# Sidewalk Design Guidelines and Existing Practices

Chapter 4

Sidewalks form the backbone of the pedestrian transportation network. According to the Institute of Transportation Engineers, Technical Council Committee 5A-5 (1998), sidewalks "reduce the incidence of pedestrian collisions, injuries, and deaths in residential areas and along two-lane roadways." Without sidewalks, public rights-of-way are inaccessible to all pedestrians, including people with disabilities. When sidewalks are not available, pedestrians are forced to share the street with motorists, access to public transportation is restricted, and children might not have safe play areas. Because Federal regulations do not require agencies to build sidewalks, the decision is left to States and local agencies. Some agencies prioritize sidewalk installation, while others do not.

Accessible pedestrian facilities should be considered part of every new public right-of-way project where pedestrians are permitted. Sidewalk installation and the linking of pedestrian routes to transportation stops and major corridors should always be a priority. The decision to install sidewalks should not be optional. "Sidewalks should be built and maintained in all urban areas, along non-Interstate public highway rights-of-way, in commercial areas where the public is invited, and between all commercial transportation stops and public areas" (Institute of Transportation Engineers, Technical Council Committee 5A-5, 1998). This chapter examines the elements and characteristics of sidewalks that have the greatest impact on access. These characteristics include grade, cross-slope, and the design of specific elements such as curb ramps, driveway crossings, and intersections.

## 4.1 Location Research

The researchers visited a variety of sidewalk locations to determine what access provisions were being made for pedestrians. Eighteen jurisdictions across the United States were selected; some were chosen for their pedestrian-friendly reputations, while others were visited because the researchers had other business in the area. Measurements were taken during these visits to determine if the access needs of people with disabilities were being addressed and where improvements needed to be made.

During the site visits, local transportation officials responsible for sidewalk design and construction were interviewed about the ways their agencies were making sidewalks more accessible. Officials contacted included engineers responsible for implementing access improvements, ADA compliance officers, pedestrian/bicycle coordinators, and planners overseeing the construction of access features for new construction and renovations.

The interviews indicated that many sidewalk professionals have a desire to make sidewalks accessible. Designers and builders are beginning to realize that the standard pedestrian is a myth and that, in reality, sidewalk users are very diverse. However, there remains a need to provide information to designers and builders on ways to develop accessible facilities within the constraints of existing facilities, as well as in new construction.

During the visits, it became clear that techniques needed to be developed to accurately measure sidewalk elements such as curb ramps, driveway crossings, and medians. Techniques to quickly and accurately assess sidewalk environments were adapted from the Universal Trail Assessment Process (UTAP), originally developed to assess access conditions on recreational trails. The tools used to measure sidewalks were identical to those used in the UTAP, with the addition of a profile gauge to record small changes in level and raised tactile surfaces (see Section 5.1 for more information about the UTAP). The terminology and measurement process was standardized to ensure consistency among personnel.

General information about each sidewalk feature was recorded, including type, dimensions, and location with respect to other sidewalk elements. A data sheet was developed for quick recording of general access information. More detailed measurements of curb ramps, driveway crossings, and medians were recorded on a separate form. Up to 10 grade segments, 8 lengths, and 6 transition heights were recorded for these elements for full characterization of the dimensions and grades of each ramp, street, and gutter.

## 4.2 Design Guideline Comparisons

In addition to visiting a variety of sidewalk locations, the researchers identified existing guidelines that could be applied to public rights-of-way. The guidelines were collected from Federal, State, and city agencies, as well as private research and advocacy organizations. Guidelines for sidewalks were compiled in Tables 4-2.1 to 4-2.4. Guidelines for curb ramps were compiled in Tables 4-3.1 to 4-3.4. Both sets of tables are located at the end of this chapter.

The degree of accessibility provided by each guideline depends on the focus of the authorizing agency or organization. For example, the design guidelines produced by the American Association of State Highway and Transportation Officials (AASHTO) focus primarily on vehicle use, whereas ADAAG emphasizes accessible design for pedestrians. The AASHTO guidelines for public rights-of-way are titled *A Policy on Geometric Design of Highways and Streets*; however, the document is commonly referred to as the *AASHTO Green Book*. This terminology will be used throughout this report to avoid confusion with the AASHTO guidelines for bicycle and shared-use paths.

The Federal accessibility guidelines (the ADA Standards for Accessible Design and UFAS) were originally developed for accessible routes in buildings and on building sites. Many of the requirements for accessible routes can be extrapolated to public rights-of-way. In 1994, the U.S. Access Board developed draft accessibility guidelines, proposed by ADAAG (1994), that specifically applied to public rights-of-way. Even though proposed Section 14 (1994) is now reserved, some State DOTs have adopted it as their accessibility standard for public rights-of-way. Some State and local transportation agencies have also developed their own standards for sidewalk design because traditional guidelines, such as the *AASHTO Green Book*, do not include comprehensive sidewalk recommendations. Other organizations, such as the Institute of Transportation Engineers and the Federal Highway Administration, have also developed sidewalk and curb ramp design recommendations.

## 4.3 Access Characteristics

The design of a sidewalk can be described by a variety of characteristics. This report focuses on sidewalk characteristics that have the greatest impact on accessibility, such as grade and surface type. Other characteristics such as location, type of street, and climate also affect the pedestrian friendliness of a sidewalk but do not directly impact access. Access characteristics directly affect usability of a sidewalk. The amount of attention paid to these details will determine whether a facility is accessible or not. Even mildly difficult features in combination can add up to an inaccessible pathway.

### 4.3.1 Grade

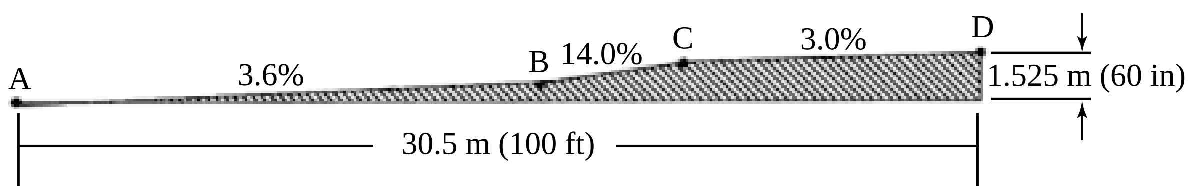
*Grade* (slope) is defined as the slope parallel to the direction of travel and is calculated by dividing the vertical change in elevation by the horizontal distance covered. For example, a path that gains 2 m in elevation over 50 m of horizontal distance has a grade of 4 percent. Although some guidelines use the term “slope” instead of “grade,” the term “grade” is used in this report to avoid confusion with cross-slope.

*Running grade* is defined as the average grade along a contiguous grade. *Maximum grade* is defined as a limited section of path that exceeds the typical running grade. In the pedestrian environment, maximum grade should be measured over 0.610 m (24 in) intervals (the approximate length of a wheelchair wheelbase, or a single walking pace). When measuring sidewalk grade, both running grade and maximum grade should be determined. Measuring running grade only does not give an accurate understanding of the sidewalk environment because small steep sections may not be detected. Figure 4-1 provides an example of a typical grade that is fairly negotiable, with a maximum grade that could be very difficult for some users to traverse. In the illustration, the running grade between Points A and D is 5 percent, but the grade between Points B and C is 14 percent. A person who could negotiate a 5 percent grade might not be able to negotiate a 14 percent grade, even for short distances.

The *rate of change of grade* is defined as the change in grade over a given distance. The rate of grade change is determined by measuring the grade and the distance over which it occurs for each segment of the overall distance. For the purposes of this report, rate of change of grade is measured over 0.610 m (2 ft) intervals, which represent the approximate length of a single walking pace and a wheelchair wheelbase (Figure 4-2). In the sidewalk environment, rate of change of grade

***Figure 4-1:***

***Maximum grades can make a sidewalk difficult to traverse, even if the overall running grade is moderate.***

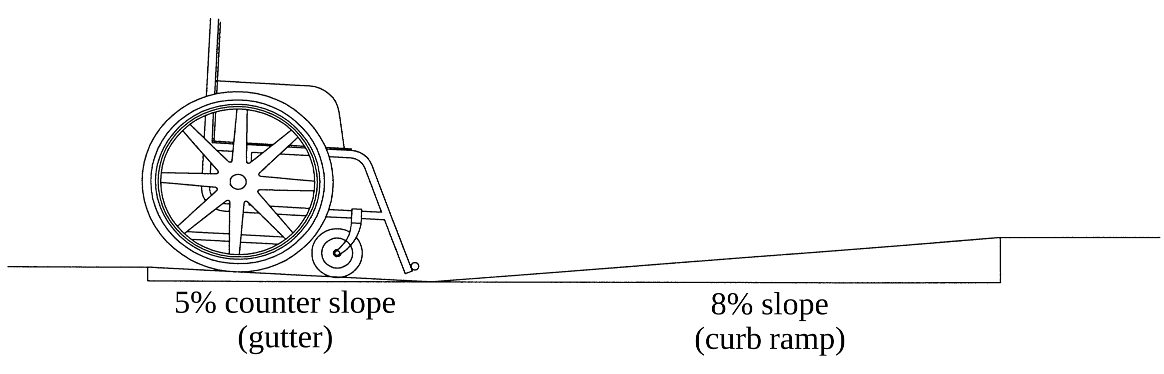



$$\text{Running Grade} = \frac{\text{Total Rise (1.525 m)}}{\text{Total Run (30.5 m)}} = 5\%$$

Maximum Grade = 14%

***Figure 4-2:***

***The gutter slopes counter to the slope of the curb ramp to promote drainage.***



should not exceed 13 percent. An example of a 13 percent change in grade occurs at a curb ramp if the slope of the gutter is 5 percent and the slope of the curb ramp is 8 percent (Figure 4-2).

If the rate of change of grade exceeds 13 percent over a 0.610 m (2 ft) interval, the ground clearance of the footrests and or antitip wheels might be compromised. Antitip wheels are placed on the back of some wheelchairs to improve stability and prevent tipping. Even wheelchair users traveling slowly can get stuck if the footrest or antitip wheels get caught.

If the rate of change of grade exceeds 13 percent, the dynamic stability of the sidewalk user can also be significantly compromised, depending on the speed at which the wheelchair user goes through the curb ramp. Dynamic stability is compromised because the negative slope of the gutter causes the wheelchair to rotate forward. However, upon reaching the bottom of the transition, the wheelchair begins to pitch back rapidly as the wheelchair travels up onto the positive slope in front of the chair (Figure 4-3). Rapid changes in grade can also cause a wheelchair user traveling with speed to flip over backward, as illustrated in Figure 4-4. Any amount of height transition between the curb ramp and the gutter can intensify problems for wheelchair users.

*Counter slope* is defined as a grade that is opposite to the general running grade of a path. For example, at a curb ramp, the slope of the gutter is generally counter to the slope of the ramp (Figure 4-2). According to ADAAG, the counter slope to a curb ramp should not exceed 5 percent (ADAAG, U.S. Access Board, 1991). If the counter slope of a curb ramp exceeds 5 percent, the rate of change of grade is likely to exceed 13 percent, depending upon the grade of the ramp.

The guidelines and recommendations that were reviewed for running grade and maximum grade are included in Tables 4-2.1 through 4-2.4, located at the end of this chapter. ADAAG and UFAS specify that the maximum grade of an accessible route on a building site be no more than 8.33 percent with a maximum rise of 0.760 m (30 in). Grades greater than 5 percent require handrails and level landings at least 1.525 m (60 in) wide. If the ramp turns, the landing dimensions should be 1.525 m x 1.525 m (60 in x 60 in). A ramp with level landings at both ends is illustrated in Figure 4-5. The distance between level landings is dependent on the grade of the ramp. For example, if the ramp grade is 8.33 percent, a level landing is required at least every 9.1 m (30 ft). However, if the grade of

***Figure 4-3:***
***Excessive slope differences between gutter and ramp can cause a wheelchair to tip forward.***

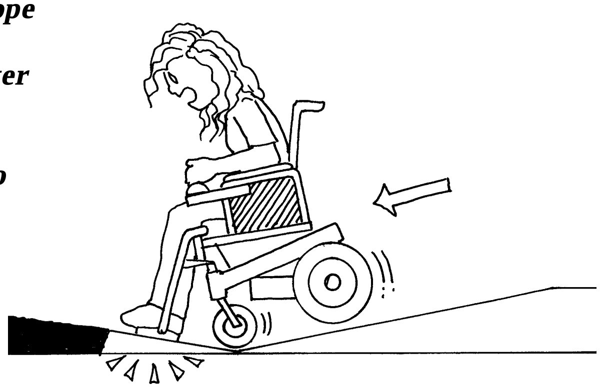


***Figure 4-4:***
***Excessive slope differences between a gutter and a ramp can cause wheelchairs to flip over backward.***

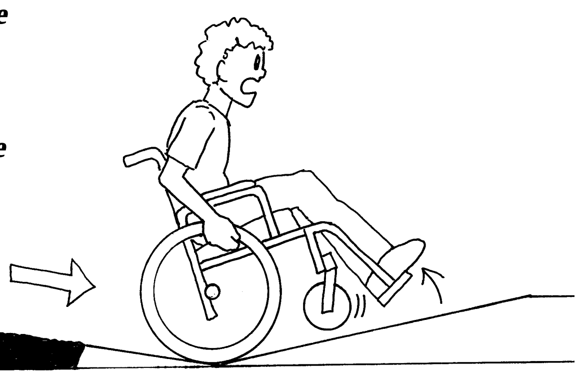
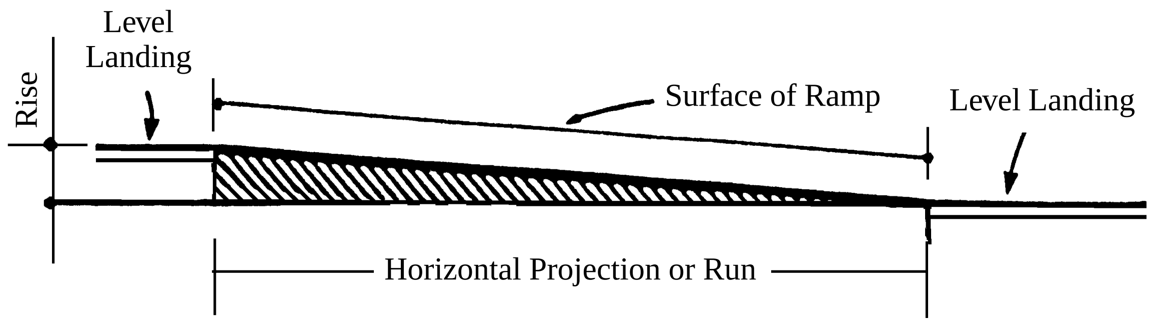


***Figure 4-5:***

***Ramps must have level landings***
***(based on ADAAG Figure 16, U.S. Access Board, 1991).***




the ramp is 6.5 percent, a level landing is required only every 12 m (40 ft). (ADAAG, U.S. Access Board, 1991; UFAS, U.S. DoD et al., 1984). Level landings provided at regular intervals allow wheelchair users and others a place to rest, turn around, and gain relief from prevailing grade demands. Level landings at storefronts and driveway crossings can also provide valuable resting spots for sidewalk users.

The *AASHTO Green Book* recommends that the running grade of sidewalks be consistent with the running grade of adjacent roadways. Section 14.2.1 (2a) in ADAAG proposed Section 14 (1994), now reserved, permits the running grade of the sidewalk to be consistent with the grade of adjacent roadways but recommends that the minimum feasible slope be used (U.S. Access Board, 1994b). State guidelines examined concur with the Federal accessibility standards, proposed Section 14 (1994), or the *AASHTO Green Book.*

### 4.3.2 Cross-Slope

*Cross-slope* is defined as the slope measured perpendicular to the direction of travel. Unlike grade, cross-slope can be measured only at specific points. Steep cross-slopes can make it difficult for wheelchair or crutch users to maintain lateral balance and can cause wheelchairs to veer downhill or into the street. Cross-slope is determined by taking measurements at intervals throughout a section of sidewalk and then averaging the values.

*Running cross-slope* is defined as the average cross-slope of a contiguous section of sidewalk. Often within the typical running cross-slope, there are inaccessible *maximum cross-slopes* that exceed the running cross-slope. The distance over which a maximum cross-slope occurs significantly influences how difficult a section of sidewalk is to negotiate.

*Rate of change of cross-slope* is defined as the change in cross-slope over a given distance. Rate of change of cross-slope can be measured by placing a digital level a specified distance before and after a maximum cross-slope. The specified distance should be about 0.610 m (2 ft) to represent the approximate stride of a pedestrian or the wheelbase of a wheelchair.

A cross-slope that changes so rapidly that there is no planar surface within 0.610 m (2 ft) could create a safety hazard. As the wheelchair moves over a surface that is severely warped, it will first balance on the two rear wheels and one front caster. As the wheelchair moves forward, it then tips onto both front casters and one rear wheel. This transition could cause the wheelchair user to lose control and tip over.

Proposed Section 14 (1994) specifies that sidewalks should lie in a continuous plane with a minimum of surface warping. Nonplanar surfaces are frequently found at driveway crossing flares and curb ramps without landings. Rapidly changing cross-slopes can cause one wheel of a wheelchair or one leg of a walker to lose contact with the ground (Figure 4-6) and also can cause walking pedestrians to stumble or fall.

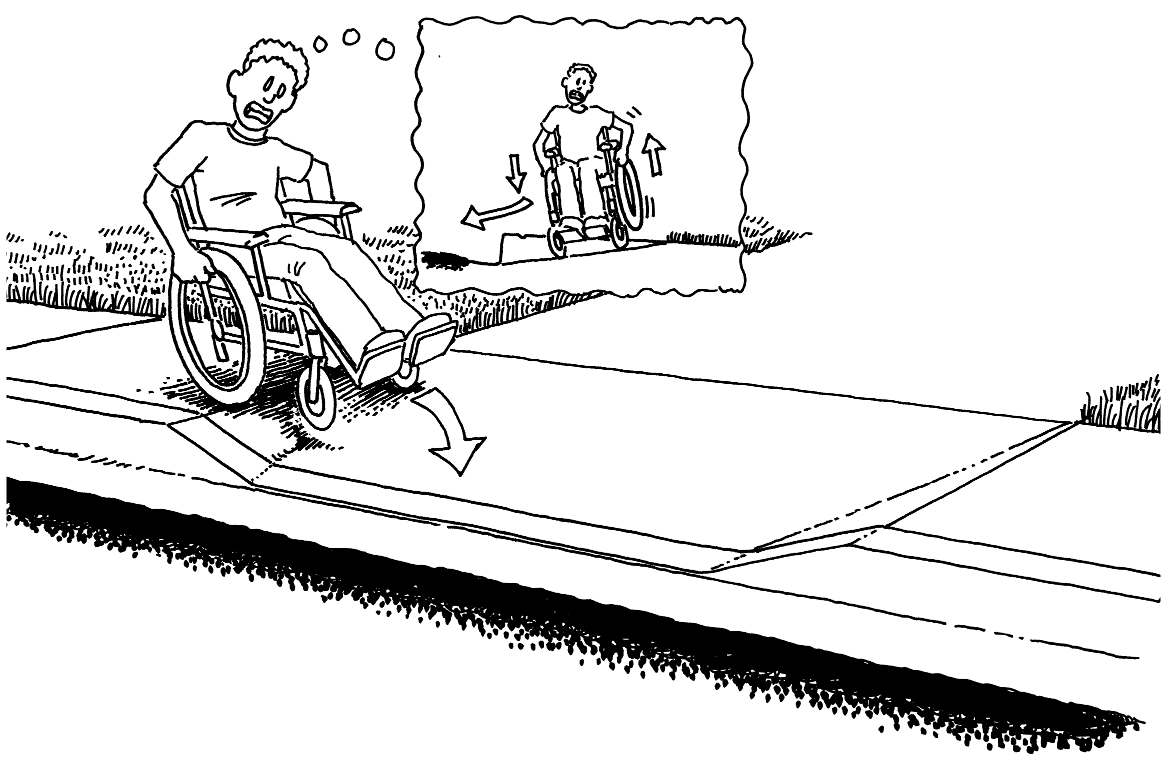
Most sidewalks are built with some degree of cross-slope, to allow water to drain into the street and to prevent water from collecting on the path. Water puddles pose a slipping hazard to sidewalk users and are even more difficult to negotiate when frozen into ice sheets in colder climates.

The guidelines and recommendations that were reviewed for running cross-slope are included in Tables 4-2.1 through 4-2.4 at the end of this chapter. ADAAG and the State pedestrian facility guidelines reviewed for this report do not permit cross-slopes to exceed 2 percent. The *AASHTO Green Book* requires the cross-slope of roads to be at least 1.5 percent to permit adequate drainage. The *AASHTO Green Book* does not provide cross-slope specifications for sidewalks. No guidelines or recommendations for maximum cross-slopes on sidewalks were identified.

### 4.3.3 Width

The widths of sidewalks not only affect pedestrian usability but also determine the types of access and other pedestrian elements that can be installed. For example, a 1.525-m (60-in) sidewalk is probably wide enough to accommodate pedestrian traffic in a residential area, but a much wider sidewalk would be necessary to include amenities such as street furniture or newspaper stands. *Design width* is defined as the width

***Figure 4-6: When cross-slopes change rapidly over a short distance, wheelchair use becomes extremely unstable.***



specification the sidewalk was intended to meet; it extends from the curb or planting strip to any buildings or landscaping that form the opposite borders of the sidewalk. *Minimum clearance width* is defined as the narrowest point on a sidewalk. An inaccessible minimum clearance width is created when obstacles such as utility poles protrude into the sidewalk and reduce the design width. A reduction in the design width could also create a minimum clearance width.

Although most guidelines require sidewalk design widths to be at least 1.525 m (60 in) wide, larger design widths can accommodate more pedestrians and improve ease of access. The *AASHTO Green Book*, the Oregon Department of Transportation guidebook, and other guidelines recommend wider design widths in areas with high volumes of pedestrians. The sidewalk width often depends on the type of street. In general, residential streets have narrower sidewalks than commercial streets.

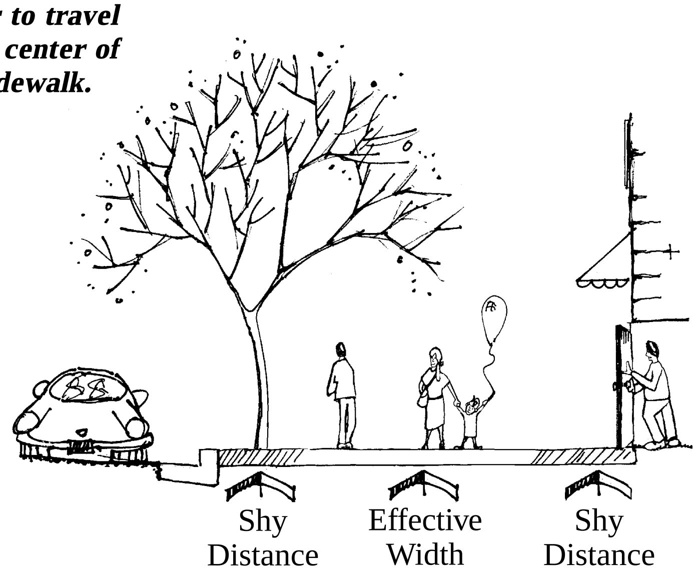
The guidelines and recommendations that were reviewed for minimum clearance width are included in Tables 4-2.1 through 4-2.4 at the end of this chapter. Most of the guidelines reviewed concur with ADAAG, which specifies that the minimum passage width for wheelchairs should be 0.815 m (32 in) at a point and 0.915 m (36 in) continuously (ADAAG, U.S. Access Board, 1991). Additional width is necessary for turning and maneuvering.

The width of the sidewalk is also affected by pedestrian travel tendencies. Pedestrians tend to travel in the center of sidewalks to separate themselves from the rush of traffic and avoid street furniture, vertical obstructions, and other pedestrians entering and exiting buildings. Pedestrians avoid the edge of the sidewalk close to the street because it often contains utility poles, bus shelters, parking meters, sign poles, and other street furniture. Pedestrians also avoid traveling in the 0.610 m (24 in) of the sidewalk close to buildings to avoid retaining walls, street furniture, and fences (OR DOT, 1995). The sidewalk area that pedestrians tend to avoid is referred to as the *shy distance*. Taking into account the shy distance, only the center 1.830 m (6 ft) of a 3.050-m (10-ft) sidewalk is used by pedestrians for travel, as shown in Figure 4-7. Thus, the effective width of a sidewalk, not the design width, constitutes the sidewalk area needed to accommodate anticipated levels of pedestrian traffic.

When right-of-way is acquired for sidewalk construction, it is important that adequate width be included to make the facility accessible. If sidewalks are not currently included, the agency responsible for sidewalk construction might consider purchasing additional right-of-way to anticipate future construction. When improving existing facilities, designers should consider purchasing additional right-of-way or narrowing the vehicle portion of the roadway.

***Figure 4-7:***

***Most pedestrians prefer to travel in the center of the sidewalk.***



### 4.3.4 Passing Space and Passing Space Interval

*Passing space* is defined as a section of path wide enough to allow two wheelchair users to pass one another or travel abreast (Figure 4-8). The passing space provided should also be designed to allow one wheelchair user to turn in a complete circle (Figure 4-9).

*Passing space interval* is defined as the distance between passing spaces. Passing spaces should be provided when the sidewalk width is narrow for a prolonged extent because of a narrow design width or continuous obstacles.

Many agencies and private organizations do not provide guidelines for passing space or passing space intervals. Those that do provide guidelines concur with ADAAG Section 4.3.4, which specifies that accessible routes with less than 1.525 m (60 in) of clear width must provide passing spaces at least 1.525 m (60 in) wide at reasonable intervals not exceeding 61 m (200 ft). If turning or maneuvering is necessary, a turning space of 1.525 m x 1.525 m (60 in x 60 in) should be provided (ADAAG, U.S. Access Board, 1991).

***Figure 4-8:***

***Passing spaces should be included at intervals on narrow sidewalks to allow wheelchair users to pass one another.***

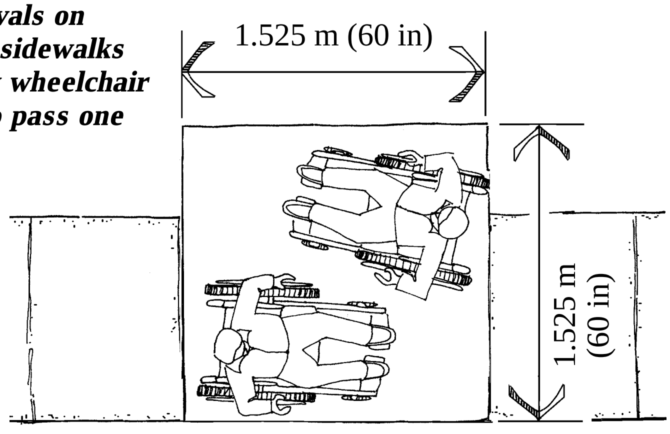
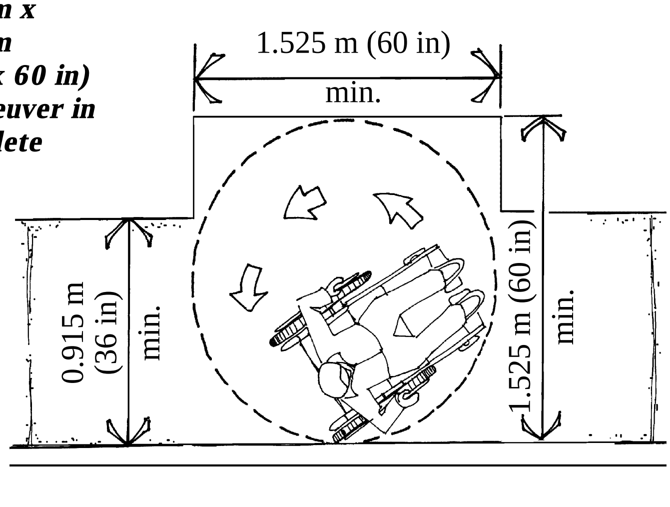



***Figure 4-9:***

***Wheelchair users require 1.525 m x 1.525 m (60 in x 60 in) to maneuver in a complete circle.***




### 4.3.5 Vertical Clearance

*Vertical clearance* is defined as the minimum unobstructed vertical passage space required along a sidewalk. Vertical clearance is often limited by obstacles such as building overhangs, tree branches, signs, and awnings.

The guidelines and recommendations that were reviewed for minimum allowable vertical clearance are included in Tables 4-2.1 through 4-2.4 at the end of this chapter. The majority of guidelines require a minimum of 2.030 m (80 in) of unobstructed vertical passage space. However, Oregon and Pennsylvania require 2.1 and 2.4 m (83 and 94 in) of vertical passage space, respectively (OR DOT, 1995; PA DOT, 1996). ADAAG states that circulation spaces, such as corridors, should have at least 2.030 m (80 in) of head room. ADAAG further specifies that if the vertical clearance of an area next to a circulation route is less than 2.030 m (80 in), elements that project into the circulation space must be protected by a barrier to warn people who are visually disabled or blind (ADAAG, U.S. Access Board, 1991).

### 4.3.6 Changes in Level

*Changes in level* are defined as vertical height transitions between adjacent surfaces or along the surface of a path. In the sidewalk environment, curbs without curb ramps, cracks (Figure 4-10), and dislocations in the surface material are common examples of changes in level. Changes in level also can result at expansion joints between elements such as curb ramps and gutters.

Changes in level can cause ambulatory pedestrians to trip or catch the casters of a manual wheelchair, causing the chair to come to an abrupt stop. People who are blind or who have low vision might not anticipate changes in level such as a buckling brick sidewalk.

The following conditions were observed to cause changes in level:

- Buckled bricks
- Cracks
- Curbs without ramps
- Drainage grates
- Grooves in concrete
- Heaving and settlement due to frost
- Lips at curb ramp frames
- Railroad tracks
- Roots
- Small steps
- Tree grates
- Uneven transitions between streets, gutters, and ramps

The guidelines and recommendations that were reviewed for changes in level are included in Tables 4-2.1 through 4-2.4 at the end of this chapter. The Federal accessibility standards permit changes in level less than 6 mm (0.25 in) high to be vertical but require changes in level between 6 mm and 13 mm (0.25 in and 0.50 in) to have a maximum bevel of 50 percent, as shown in Figure 4-11. A ramp is required for changes in level that exceed 13 mm (0.50 in) (US DOJ, 1991; UFAS, U.S. DoD et al., 1984).

### 4.3.7 Grates and Gaps

*A grate* is a framework of latticed or parallel bars that prevents large objects from falling through a drainage inlet but permits water and some debris to fall through the slots (Figure 4-12). A *gap* is defined as a single channel embedded in the travel surface of a path. Gaps are often found at intersections where railroad tracks are embedded into the road surface.

***Figure 4-10:***

***Changes in level are often caused by tree roots that break through the sidewalk surface.***

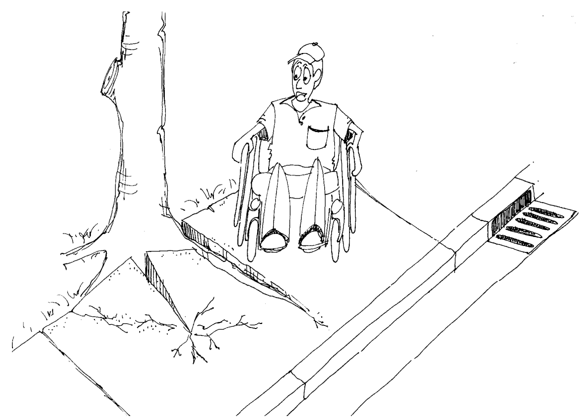


***Figure 4-11:***

***Vertical and beveled changes in level*** ***[ADAAG, Figure 7 (c, d), U.S. Access Board, 1991].***

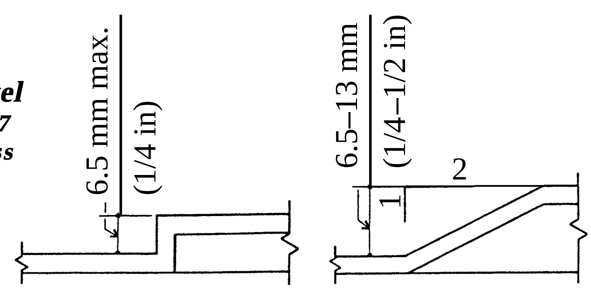
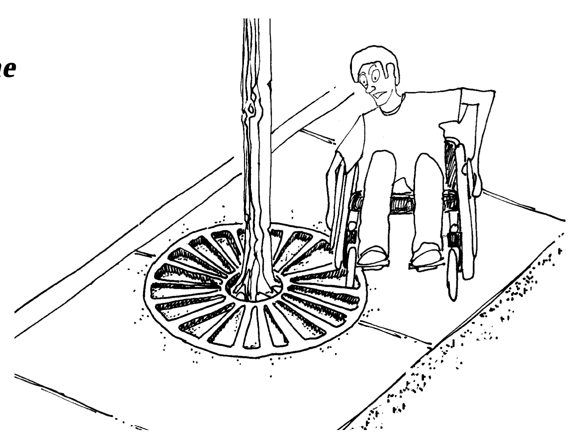



***Figure 4-12:***

***Wheelchair casters and cane and crutch tips can easily get caught in wide grates.***



Wheelchair casters and crutch tips can get caught in poorly aligned grate and gap openings. ADAAG specifies that grates located in walking surfaces should have spaces no greater than 13 mm (0.5 in) wide in one direction. It also states that gratings with elongated openings should be oriented so that the long dimension is perpendicular to the dominant direction of travel (ADAAG, U.S. Access Board, 1991). Although ADAAG does not directly address gaps, the similarity of a gap to a single grate slot suggests that ADAAG's grate specifications also apply to gaps.

### 4.3.8 Obstacles and Protruding Objects

*Obstacles* in the pedestrian environment are defined as objects that limit the vertical passage space, protrude into the circulation route, or reduce the clearance width of the sidewalk. Obstacles with large overhangs that protrude into the path of travel can be hazardous for people with visual impairments if they are difficult to detect. The full width of the circulation path should be free of protruding objects. Obstacles that reduce the minimum clearance width, such as decorative planters on a narrow sidewalk, can create significant barriers for wheelchair or walker users.

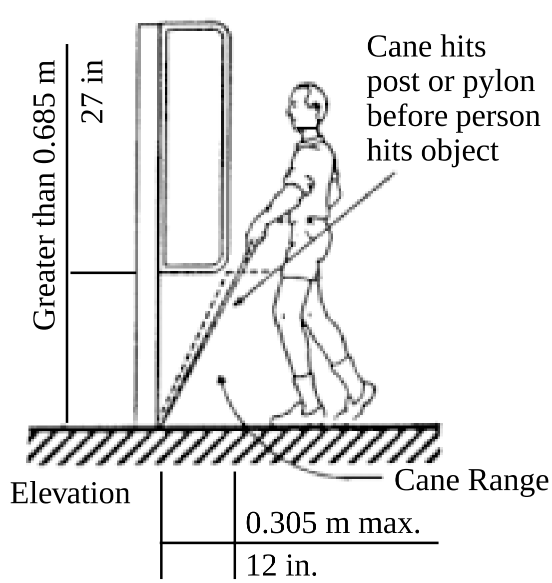



***Figure 4-13:***

***Obstacles mounted on posts should not protrude more than 0.305 m (12 in) into a circulation corridor***
***[ADAAG, Figure 8(d), U.S. Access Board, 1991].***

Most guidelines for accessibility concur with the ADAAG specifications for protruding objects. ADAAG states that objects projecting from walls that have leading edges between 0.685 m and 2.030 m (27 in and 80 in) should not protrude more than 100 mm (4 in) into walks and passageways. Freestanding objects mounted on posts or pylons may overhang a maximum of 0.305 m (12 in) from 0.685 m to 2.030 m (27 in to 80 in) above the ground (ADAAG, U.S. Access Board, 1991), as shown in Figure 4-13.

During the sidewalk assessments, potential obstacles and protruding objects were measured as they occurred along the sidewalk. Characteristics of obstacles measured in the sidewalk assessment include height, amount of overhang over the supporting structure (if any), and minimum clearance width around the obstacle.

The following objects can make a sidewalk difficult for some users to traverse if they protrude into the pathway or reduce the vertical or horizontal clear space:

- Awnings
- Benches
- Bike racks
- Bollards
- Cafe tables and chairs
- Drinking fountains
- Fire hydrants
- Folding business signs
- Grates
- Guy wires
- Landscaping
- Mailboxes (public and private)
- Newspaper vending machines

- Parking meters
- Planters
- Public telephones (mounted)
- Puddles
- Signal control boxes
- Sign poles
- Snow
- Street vendors' carts
- Street light poles
- Street sculptures
- Telephone booths
- Telephone/utility poles and their stabilizing wires
- Traffic sign poles
- Transit shelters
- Trash bags and cans
- Tree, bush, and shrub branches
- Utility boxes

### 4.3.9 Surface

*Surface* is defined as the material on which a person walks or wheels in the pedestrian environment. The type of surface often determines how difficult an area is to negotiate. For example, wood floors can be traversed without much difficulty by most people, while a gravel surface can be impossible for some people, especially wheelchair users, to cross. Surfaces in sidewalk environments are generally concrete or asphalt but commonly include tile, stone, and brick.

Most guidelines for accessibility adhere to ADAAG, which defines accessible surfaces as firm, stable, and slip-resistant. Firm and stable surfaces resist deformation, especially by indentation or the movement of objects. For example, a firm and stable surface, such as concrete, resists indentation from the forces applied by a walking person's feet and reduces the rolling resistance experienced by a wheelchair (U.S. Access Board, 1994a). When a pedestrian or wheelchair user crosses a surface that is not firm or stable, energy that would otherwise cause forward motion deforms or displaces the surface instead.

A slip-resistant surface provides enough frictional counterforce to the forces exerted in ambulation to permit effective travel (ibid.). For example, a slip-resistant surface prevents a person's shoes, crutch tips, or tires from sliding across the surface while bearing weight. A broom finish is used on many concrete sidewalks to provide sufficient slip resistance for pedestrians. The *AASHTO Green Book* requires sidewalks to have all-weather surfacing. The surface texture of curb ramps should be coarse enough to provide slip resistance when wet.

Although asphalt and concrete are the most common surfaces for sidewalks, many sidewalks are designed using brick or cobblestones. Although these surfaces are decorative, they increase the amount of work required for mobility. In addition, brick and cobblestone have inherent changes in level that are often tripping hazards. Alternatives to brick sidewalks include colored concrete stamped to look like brick, and asphalt or concrete paths with brick trim. Both alternatives preserve the decorative quality of brick but are easier for people with disabilities to negotiate.

## 4.4 Sidewalk Elements

### 4.4.1 Curb Ramps

Curb ramps provide critical access between the sidewalk and the street for people with mobility impairments. Without curb ramps, people who use wheelchairs cannot access the sidewalk. Curb ramps are most commonly found at intersections but may also be used at midblock crossings and medians. The implementing regulations for Title II of the ADA require curb ramps to be included in all new construction of sidewalks. The regulations also require curb ramps to be installed where existing pedestrian walkways cross a curb or other barrier (US DOJ, 1994b). Although no city surveyed has installed curb ramps in all existing pedestrian walkways, some cities have initiated aggressive plans calling for up to 500 curb ramp installations per year.

#### 4.4.1.1 Curb ramp components

Although there are a variety of curb ramp designs, each type of curb ramp comprises some or all of the following elements, which are illustrated in Figure 4-14:

- *Landing* — level area of sidewalk at the top of a curb ramp facing the ramp path.
- *Approach* — section of the accessible route flanking the landing of a curb ramp. The approach may be slightly graded if the landing level is below the elevation of the adjoining sidewalk.
- *Flare* — sloped transition between the curb ramp and the sidewalk. The path along the flare has a significant cross-slope and is not considered an accessible path of travel. When the sidewalk is set back from the street, returned curbs often replace flares (see Figure 4-20, p. 44).
- *Ramp* — sloped transition between the street and the sidewalk where the grade is constant and the cross-slope is at a minimum (preferably less than 2 percent).
- *Gutter* — trough or dip used for drainage purposes that runs along the edge of the street and the curb or curb ramp.

***Figure 4-14:***

***Components of a curb ramp.***

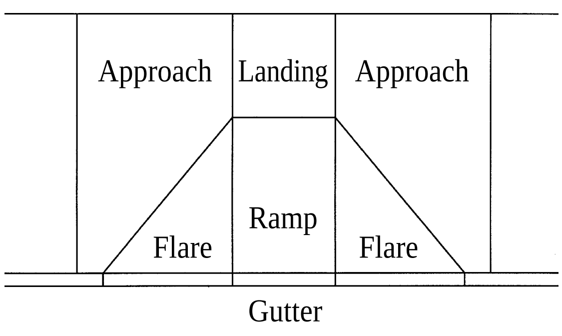
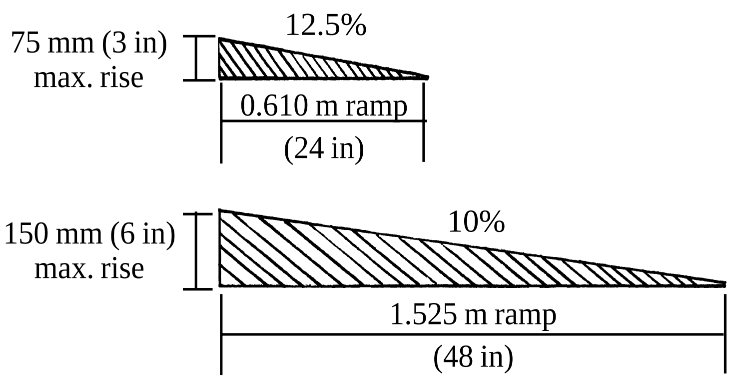



***Figure 4-15:***

***Alternative slope profiles for alterations when an 8.33 percent slope is not achievable.***




#### 4.4.1.2 Curb ramp specifications

Curb ramps should be designed to minimize the grade, cross-slope, and changes in level experienced by users. Most agencies use standard drawings to design curb ramps. Some of these guidelines are compiled in Tables 4-3.1 to 4-3.4 at the end of this chapter. The majority of the guidelines reviewed agree with ADAAG Section 4.7 specifications for curb ramps.

##### *4.4.1.2.1 Ramps*

According to ADAAG, the slope of a curb ramp should not exceed 8.33 percent, and the cross-slope should not exceed 2 percent. ADAAG also states that the least severe slope should be used in every situation. In retrofitting situations in which space prohibits the installation of an 8.33 percent ramp, ADAAG allows a slope between 8.33 percent and 10 percent for a maximum rise of 150 mm (6 in) or a slope between 10 percent and 12.5 percent for a maximum rise of 75 mm (3 in) (ADAAG, U.S. Access Board, 1991), as demonstrated in Figure 4-15.

Curb ramp widths should depend on the volume of pedestrian traffic at the specified intersection. Although ramp widths are permitted to vary, they must always be wide enough for comfortable use by wheelchair users. For this reason, ADAAG specifies that curb ramps should be at least 0.915 m (36 in) wide, not including the width of the flared sides (ADAAG, U.S. Access Board, 1991). The *AASHTO Green Book* states that curb ramps, a minimum of 1.0 m (39 in) wide or of the same width as the approach sidewalk, should be provided at crosswalks (AASHTO, 1995).

Curb ramps that are too wide and curb ramps with gradual slopes are difficult for pedestrians with visual impairments to detect. Adding a 0.610 m (2 ft) detectable warning at the bottom of these types of ramps will improve detectability. In many cities, grooves, which are intended to work as detectable warnings, are placed along the top of the ramp and/or on the ramp surface. However, grooves are difficult for people with visual impairments to detect. In addition, detectable warnings are most effective if placed at the location of the hazard. For sidewalks, the hazard occurs at the transition point between the sidewalk and the street. Section 4.4.2 contains additional information for pedestrians with visual impairments.

#### *4.4.1.2.2 Gutters*

The slopes of adjacent gutters and streets significantly affect the overall accessibility of curb ramps. When the rate of change of grade between the gutter and the ramp exceeds 13 percent over a 0.610-m (2-ft) interval, wheelchair users can lose their balance. Any amount of height transition between the curb ramp and the gutter can compound the difficulties caused by rapidly changing grades. According to ADAAG, the slope of the road or gutter surface immediately adjacent to the curb ramp should not exceed 5 percent, and the transition between the ramp and the gutter should be smooth (ADAAG, U.S. Access Board, 1991). Section 4.3.1 contains additional information on rate of change of grade.

#### *4.4.1.2.3 Landings*

Curb ramp landings allow people with mobility impairments to move completely off the curb ramp and onto the sidewalk, as shown in Figure 4-16. Curb ramps without landings force wheelchair users entering the ramp from the street, as well as people turning the corner, to travel on the ramp flares (Figures 4-17 and 4-18). According to ADAAG, the landing should be a level surface at least 0.915 m (36 in)

***Figure 4-16:***
***This wheelchair user is maneuvering successfully at a curb ramp because a level landing is provided.***

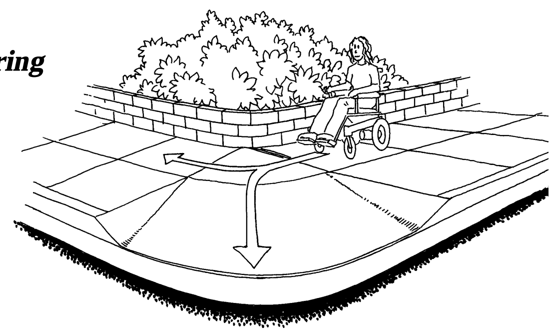


***Figure 4-17:***
***This wheelchair user will have difficulty entering the sidewalk because the curb ramp lacks a landing.***

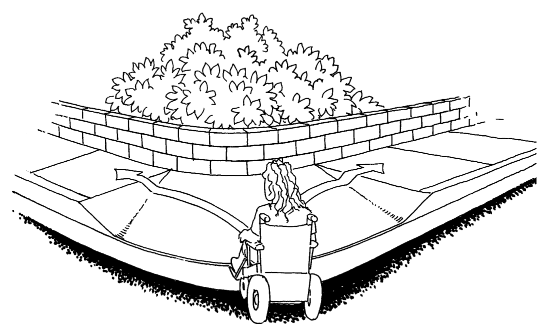
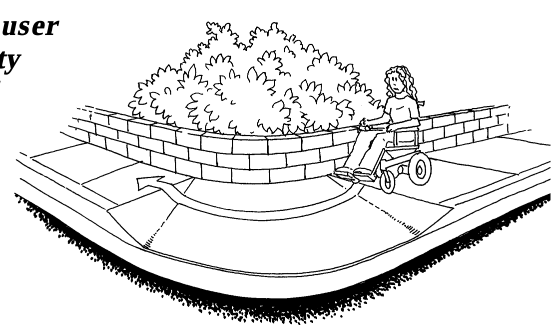


***Figure 4-18:***
***This wheelchair user will have difficulty traveling around the corner because the curb ramp lacks a landing.***



wide to prevent pedestrians from having to cross the curb ramp flare. ADAAG Section 14 (1994) recommends a 1.220-m (48-in) landing for perpendicular curb ramps and a 1.525-m (60-in) landing for parallel curb ramps (U.S. Access Board, 1994b).

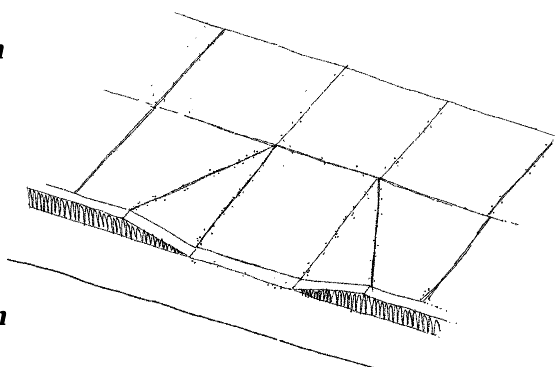


***Figure 4-19:***

***Flares provide a sloped transition between the ramp and the surrounding sidewalk and are designed to prevent ambulatory pedestrians from tripping.***

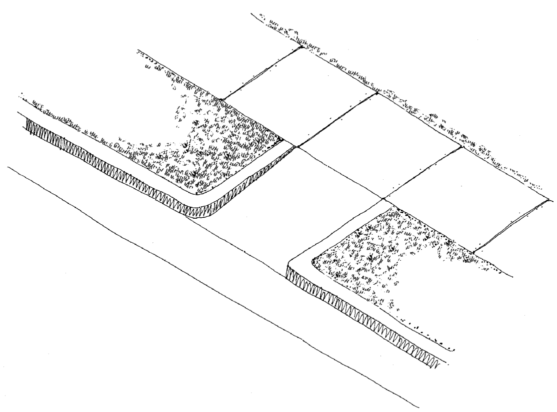


***Figure 4-20:***

***Returned curbs may be used when the curb ramp is located outside the pedestrian walkway, such as in a planting strip.***

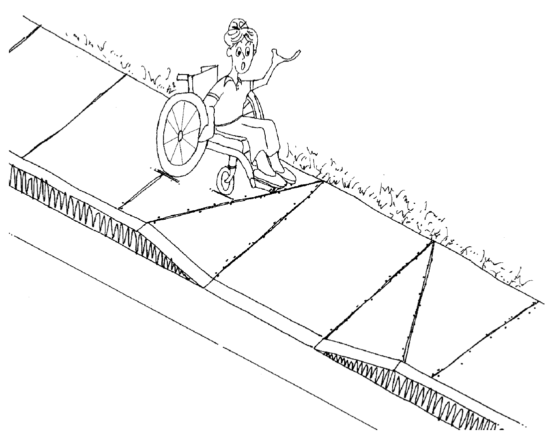


***Figure 4-21:***

***Without level landings, perpendicular curb ramps are problematic for wheelchair users and others to travel across.***

### *4.4.1.2.4 Flares*

The flared sides of curb ramps provide a graded transition between the ramp and the surrounding sidewalk (Figure 4-19). Flares are not considered an accessible path of travel because they are generally steeper than the ramp and often feature significant cross-slopes with excessive rate of change of cross-slope. According to ADAAG, if the landing width is less than 1.220 m (48 in), then the slope of the flares at the curb face should not exceed 8.33 percent. If the landing width is greater than 1.220 m (48 in), a 10 percent slope is acceptable (ADAAG, U.S. Access Board, 1991). If the curb ramp is located where a pedestrian might normally walk, flares are useful indicators to people with visual disabilities. Flares may be replaced with returned curbs if the curb ramp is located where a pedestrian does not have to walk across the ramp or if the sides are protected by guardrails or handrails (Figure 4-20).

### 4.4.1.3 Curb ramp types

Curb ramps can be configured in a variety of patterns, depending on the location, type of street, and existing design constraints. Curb ramps are often categorized by their position relative to the curb line. The three most common and basic configurations are termed perpendicular, parallel, and diagonal.

### *4.4.1.3.1 Perpendicular curb ramps*

The path of travel along a perpendicular curb ramp is oriented at a 90-degree angle to the curb face. Perpendicular curb ramps are difficult for wheelchair users to negotiate if they do not have a level landing (Figure 4-21). When the sidewalk is very narrow, it can be costly to purchase additional right-of-way to accommodate a landing for perpendicular curb ramps. An alternative to purchasing more land is to extend the corner into the parking lane with a curb extension (also known as a *bulbout*). In addition to providing space for a level landing, curb extensions calm traffic, reduce the crossing distance, and provide a larger refuge for pedestrians to congregate while waiting to cross the street (reference Section 4.4.9 for additional information on curb extensions). An additional option for providing landings is to increase the overall width of the sidewalk by adding right-of-way from the roadway. Perpendicular curb ramps are often installed in pairs at a corner (Figure 4-22). For new construction, Section 14 (1994) proposed that two perpendicular curb ramps with level landings should be provided at street crossings. This recommendation was included because two accessible perpendicular curb ramps are generally safer and more usable for pedestrians than a single curb ramp.

#### 4.4.1.3.2 Diagonal curb ramps

Diagonal curb ramps are single curb ramps installed at the apex of a corner (Figure 4-23). Diagonal curb ramps force pedestrians descending the ramp to proceed into the intersection before turning to the left or right to cross the street. This puts them in danger of being hit by turning cars. A marked clear space of 1.220 m (48 in) at the base of diagonal curb ramps is necessary to allow ramp users in wheelchairs enough room to maneuver into the crosswalk (Figure 4-23) (ADAAG, U.S. Access Board, 1991). A designer's ability to create a clear space at a diagonal curb ramp might depend on the turning radius of the corner. For example, a tight turning radius requires the crosswalk line to extend too far into the intersection and exposes pedestrians to being hit by oncoming traffic. In many situations, diagonal curb ramps are less costly to install than two perpendicular curb ramps. Although diagonal curb ramps might save money, they create potential safety and mobility problems for pedestrians, including reduced maneuverability and increased interaction with turning vehicles, particularly in areas with high traffic volumes. Diagonal curb ramps are not

***Figure 4-22:***

***Two perpendicular curb ramps with level landings maximize access for pedestrians at intersections.***

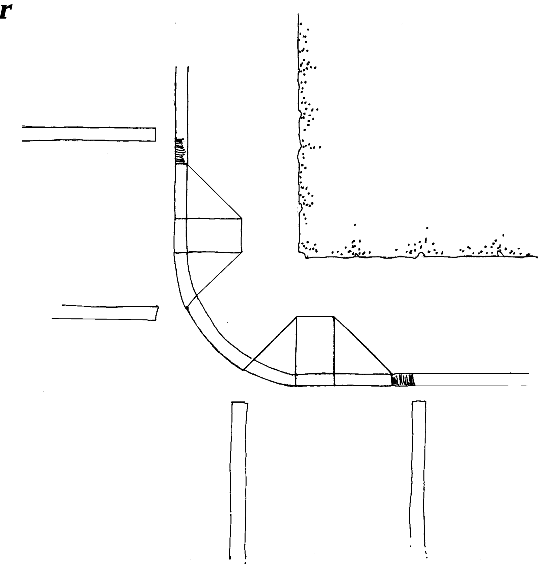
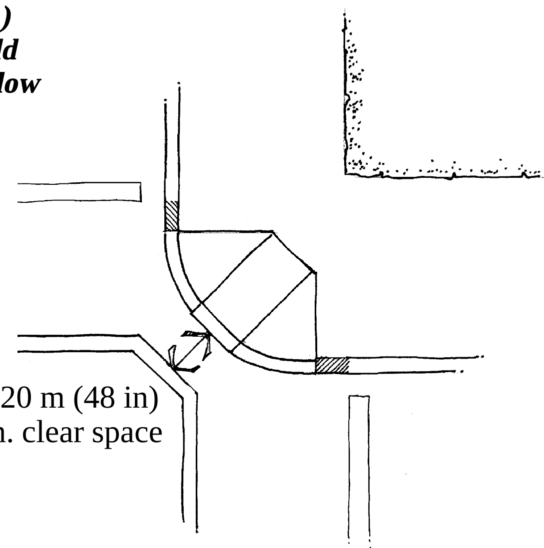


***Figure 4-23:***

***If diagonal curb ramps are installed, a 1.220-m (48-in) clear space should be provided to allow wheelchair users enough room to maneuver into the crosswalk.***




desirable in new construction but might be effective in retrofitting if there is not enough space for two accessible perpendicular curb ramps.

#### 4.4.1.3.3 Parallel curb ramps

The path of travel along a parallel curb ramp is a continuation of the sidewalk, as

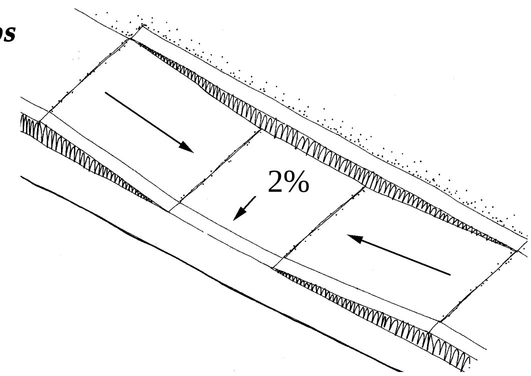



***Figure 4-24:***

***Parallel curb ramps work well on narrow sidewalks but require users continuing on the pathway to negotiate two ramp grades.***

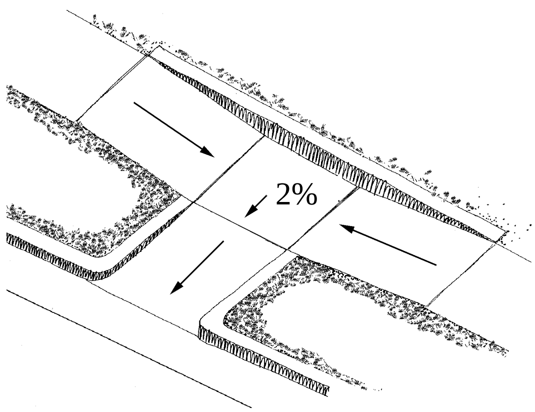



***Figure 4-25:***

***A combination curb ramp is a creative way to avoid steep curb ramps and still provide level landings.***

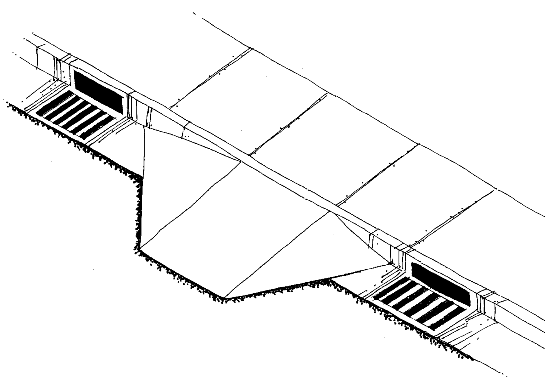


***Figure 4-26:***

***Built-up curb ramp with drainage inlets.***

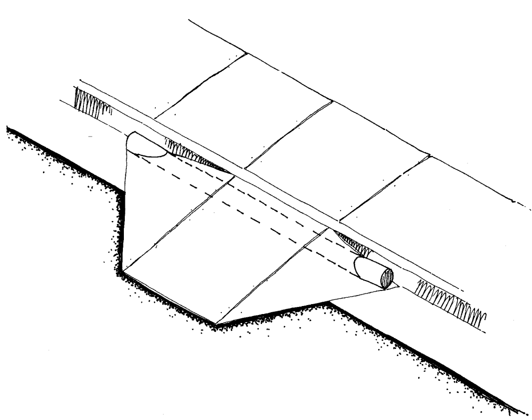


***Figure 4-27:***

***Built-up curb ramp with a drainage pipe.***

shown in Figure 4-24. Parallel curb ramps provide an accessible transition to the street on narrow sidewalks. However, if the landing on parallel curb ramps is not sloped toward the gutter (no more than 2 percent), water and debris can pool there and obstruct passage along the sidewalk. Parallel curb ramps also require those wishing to continue along the sidewalk to negotiate two ramp grades, unless a wide buffer zone permits the sidewalk to be set back behind the ramps. A combination perpendicular and parallel ramp will significantly reduce the ramp grades for people who wish to continue along the sidewalk (Figure 4-25).

#### *4.4.1.3.4 Built-up curb ramps*

Built-up curb ramps are oriented in the same direction as perpendicular curb ramps but project out from the curb. For this reason, built-up curb ramps can be installed on narrow sidewalks but are most often installed in parking lots. If an edge protection is not provided on built-up curb ramps between the ramp and the sidewalk, people with visual disabilities might not be able to distinguish between the sidewalk and the street. According to ADAAG, built-up curb ramps should not extend into a vehicular traffic lane (ADAAG, U.S. Access Board, 1991). Built-up curb ramps also should not extend into bicycle lanes because they might present a hazard for cyclists.

Built-up curb ramps have additional drainage requirements because they block the gutter. Possible solutions include providing drainage inlets or placing a drainage pipe under the curb ramp (Figures 4-26 and 4-27).

### 4.4.1.4 Curb ramp placement

In addition to specifying curb ramp designs, most transportation agencies provide specifications for their placement. Curb ramp placement can be especially complicated in retrofit situations.

Relocating or redesigning the intersection and street furniture can be expensive. Many sidewalk characteristics, including width, elevation of buildings, and position of street furniture, can affect the curb ramp design chosen. In retrofit situations in which sidewalk width is limited, parallel curb ramps might provide more gradual slopes and landings.

Curb ramps that force users to cross storm drain inlets often present hidden risks to pedestrians. The grates covering such inlets can catch the casters of wheelchairs or the tips of canes and walkers, causing falls and injuries. Water at the base of curb ramps can obscure the transition from the ramp to the gutter and cause pedestrians to misjudge the terrain. Puddles at the base of curb ramps can also freeze and cause users to slip. Locating drain inlets uphill from curb ramps will reduce the amount of water that collects at the base.

Curb ramps ending in parking spaces are not usable when blocked by parked vehicles. This situation can be prevented through parking enforcement and warning signs but perhaps more effectively through the use of curb extensions (see Section 4.4.9 for additional information on curb extensions).

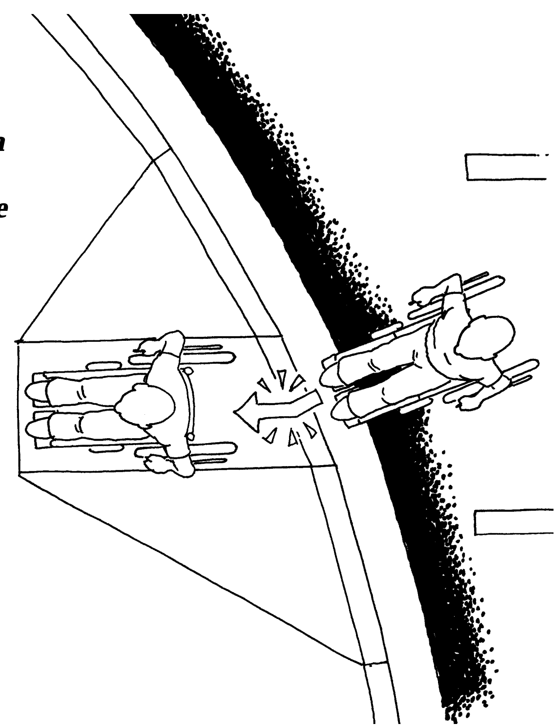
Perpendicular curb ramps should be built 90 degrees to the curb face. At a corner with a tight turning radius, a perpendicular curb ramp built 90 degrees to the curb face will be oriented toward the crosswalk. This is helpful to users because they can follow the ramp path directly across the street. Curb ramps aligned with the crosswalk also reduce the maneuvering that wheelchair users must perform to use the ramp.

At corners with larger turning radii, the curb ramp cannot always point in the direction of the crosswalk and be perpendicular to the curb face. In some cities, designers align curb ramps parallel to the crosswalk, causing the ramp face to be skewed. This design has some benefit to people with visual impairments because they can use the path of the curb ramp to direct them across the street. However, people with visual impairments tend not to rely on the direction of curb ramps because of the abundance of diagonal curb ramps that point into the center of the street.

In addition, if the curb ramp is not perpendicular to the curb, as illustrated in Figure 4-28, wheelchair users have to negotiate changing cross-slopes and changing grades simultaneously, or they have to turn while making the grade transition. Turning at the grade transition requires a wheelchair user traveling down a curb ramp to go down one edge of the ramp and try to turn while on a significant grade. Curb ramps that are perpendicular to the curb prevent wheelchair users from

***Figure 4-28:***

***To avoid having to negotiate changing grades and changing cross-slope simultaneously, a wheelchair user has to turn at the grade transition.***

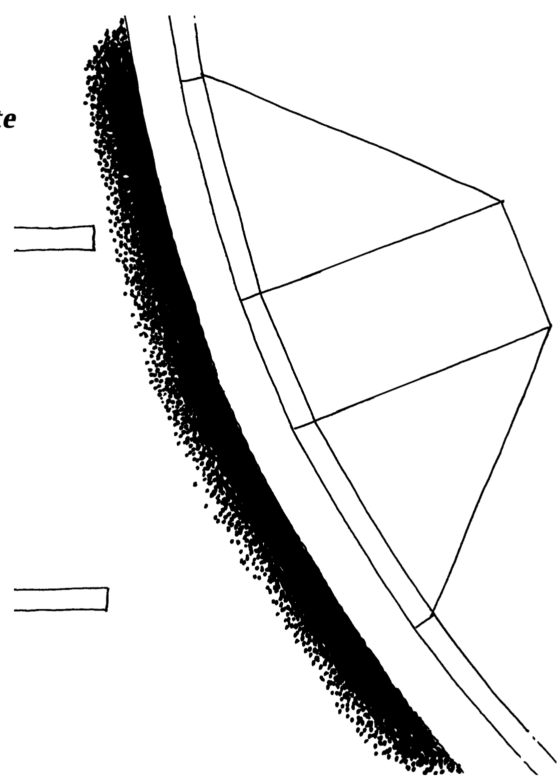


having to turn at the ramp to a gutter transition (Figure 4-29).

#### 4.4.1.5 Curb ramps and people with visual impairments

People with visual impairments do not use curb ramps in the same manner as people with mobility impairments. Although people with visual impairments can obtain helpful navigational cues from perpendicular curb ramps, they can learn the same information from the edge of the curb. Curb ramps and flare slopes that are steep enough relative to the grade of the surrounding sidewalk are more detectable than gradually sloped curb ramps or depressed corners (GA Institute of Technology, 1979). If people with visual impairments are unable to detect a curb ramp, they will not know that they are moving into the street. Installing detectable warnings on ramps can help people with visual impairments detect the upcoming intersection (see Section 4.4.2). Some States also require minimum curb ramp slopes to improve detectability for people with visual impairments.

***Figure 4-29: Curb ramps designed with the ramp perpendicular to the curb eliminate rapidly changing grades and cross-slopes at the grade transition.***



It is commonly believed that the orientation of curb ramps helps people with visual impairments determine the direction of the crosswalk. However, this technique is generally not taught or used because many curb ramps are not aligned with the path of travel across the street. The skew of diagonal curb ramps can be a particular source of confusion to people with visual impairments if other sidewalk cues present conflicting information about the intersection. Some dog-guide users interviewed for this project said they were most wary of diagonal curb ramps because their dogs might follow the curb ramp path out into the middle of the intersection. However, most people with visual impairments interviewed said that while a diagonal slope to the sidewalk indicated the presence of an intersection, they used other cues, such as the sound of traffic, to orient for the crossing.

### 4.4.2 Conveying Information to Pedestrians with Visual Impairments

All pedestrians must obtain a certain amount of information from the environment to travel along sidewalks safely and efficiently. Most pedestrians obtain this essential information visually, by seeing such cues as intersections, traffic lights, street signs, and traffic movements. People with visual impairments also use cues in the environment to travel along sidewalks. For example, the sound of traffic, the slope of curb ramps, changes in surface texture, and a shadow from an overhead awning serve as primary indicators of an upcoming intersection for people with visual impairments. Blind pedestrians also use their ability to estimate distances and directions they have walked (dead reckoning) to determine their location relative to desired destinations (Long and Hill, in Blasch et al., 1997).

Good design in the form of regularly aligned streets, simple crossing patterns, and easy-to-understand city layouts is generally the best method to provide good orientation cues for pedestrians with visual impairments. However, accessible information might be needed in some situations to supplement existing information. Locations where supplementary information is most beneficial include irregular intersections, open spaces such as plazas, raised intersections, and curb ramps with a slope less than 8.33 percent.

Some cues that people with visual impairments use are permanent, such as the edge of the curb; other cues, such as the sound of traffic, are intermittent. Although the sound of traffic is a very effective way for people with visual impairments to identify an intersection, it is unreliable because cars are not always present. Another issue that affects the usefulness of cues is a person's familiarity with the environment. For example, a person who lives near an intersection with a pedestrian-actuated control signal might be able to identify it easily because of repeated use and familiarity with its presence. However, a person who is unfamiliar with the intersection would be less likely to detect such a device. The most reliable cues for people with visual impairments are permanent and can be detected even in unfamiliar environments.

People with visual impairments should have access to the same information as sighted pedestrians when traveling in unfamiliar areas. To accommodate all pedestrians, it is important to provide information that can be assimilated using more than one sense. For example, an intersection that contains a raised tactile surface warning, a WALK signal light, and an audible pedestrian signal would be more accessible than an intersection that provides only a WALK signal light. Redundancy and multiplicity of formats increase the likelihood that people with impairments and others will be able to make informed traveling decisions.

The most effective accessible information is easy to locate and intuitive to understand, even for pedestrians who are unfamiliar with an area. People with visual impairments stress the importance of consistency in design because accessible information added to the environment is most useful "when used in consistent locations so that the traveler can rely on their existence" and find them reliably (Peck and Bentzen, 1987). Users would benefit if each type of accessible indicator were exclusively reserved to indicate a specific situation in the pedestrian environment and consistently installed to avoid conveying conflicting and confusing information. Studies in the United Kingdom have shown that pedestrians with visual impairments can reliably detect, distinguish, and remember a limited number of different tactile paving surfaces and the distinct meanings assigned to them (Department of the Environment, Transport, and the Regions, Scottish Office, Notified Draft, 1997).

Visual, auditory, and tactile perceptual information is very useful in detecting cues and landmarks essential to wayfinding and is also important in detecting obstacles and hazards. Mobility is defined as "the act or ability to move from one's present position to one's desired position in another part of the environment safely, gracefully, and comfortably." Wayfinding is defined as "the process of navigating through an environment and traveling to places by relatively direct paths" (Long and Hill, in Blasch et al., 1997). The long cane is a primary example of an environmental probe that allows blind pedestrians to acquire perceptual information about their immediate environment systematically and efficiently. The long cane helps users establish and maintain orientation, as well as detect and avoid hazards.

Because people with visual impairments obtain information about the environment in many ways, the most effective cues convey information in more than one format. For example, truncated domes can be detected not only by texture but by sound and color contrast as well. The greater number of sensory qualities (color, texture, resilience, and sound) the cue has, the more likely it will be detected and understood (Sanford and Steinfeld, 1985). The following are common types of accessible information added to sidewalk environments:

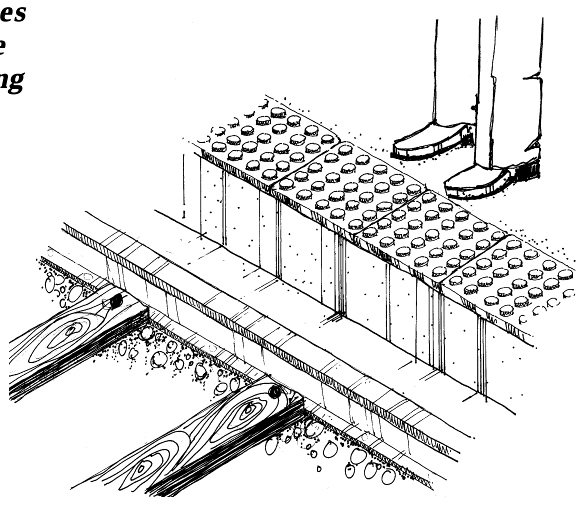
- Raised tactile surfaces used as detectable warnings
- Raised tactile surfaces used for wayfinding
- Materials with contrasting sound properties
- Grooves
- Contrasting colors for people with low vision
- Audible and vibrotactile pedestrian signals

#### 4.4.2.1 Raised tactile surfaces used as detectable warnings

Raised tactile surfaces used as warnings employ textures detectable with the touch of a foot or sweep of a cane to indicate upcoming hazards or changes in the pedestrian environment. Many different types of raised tactile surfaces have been proven to be detectable by people with visual disabilities. However, tactile surfaces used as detectable warnings should meet the technical specifications in ADAAG (see Section 4.4.2.7) to avoid confusion with tactile surfaces used for wayfinding. Raised tactile surfaces include truncated domes, patterned panels, and other textured designs. Tactile surfaces used as detectable warnings must also provide color contrast with surrounding surface materials.

*Figure 4-30:*

*Truncated domes are an effective way of indicating a drop-off at transit platform.*



Raised tactile surfaces have been shown to be very effective in actual application. BART in the San Francisco Bay Area and METRO DADE transit in Miami have used raised tactile surfaces as systemwide warnings on platform edges since 1989 and have documented no instances of rider dissatisfaction with truncated dome surfaces (Figure 4-30). In contrast, the overall incidence of trips, slips, and falls at platform edges has been significantly reduced. In addition, BART riders exhibit an increased sense of drop-off awareness by tending to “stand farther from the platform edge than MUNI (San Francisco) riders standing at different tracks in the same stations but lacking detectable warnings” (Bentzen, Nolin, and Easton, 1994).

Domes with truncated tops are generally more comfortable than other dome designs for pedestrians to travel across (O’Leary, Lockwood, Taylor, and Lavely, 1995). Low truncated domes have been used to provide warning information in a number of countries, including the United Kingdom (Department of the Environment, Transport, and the Regions, Scottish Office, Notified Draft, 1997), and Japan (Sawai, Takato, and Tauchi, 1998). In the United States, truncated domes are required at transit platform drop-offs (US DOJ, 1991; US DOT, 1991).

The detectability of raised tactile surfaces can depend upon the degree of contrast between the surface and the surrounding surface materials. For example, raised detectable surfaces have been shown to be significantly less detectable when located adjacent to coarse aggregate concrete (Bentzen, Nolin, Easton, Desmarais, and Mitchell, 1994). Raised surfaces are thus much more effective when placed next to smooth paving materials such as brushed concrete.

Climate can determine what type of detectable surface is most appropriate for a region. For example, ice was found to obscure the textural contrast of some raised surface materials (U.S. Access Board, 1985). Surfaces that withstand scraping by snowplows, minimize the collection of precipitation such as snow and ice, and resist degradation by snow-melting additives such as salt are most effective in colder areas. Some cities in the United States have discontinued the use of truncated domes at curb ramps because the materials used wore down quickly and could not be plowed free of snow. However, New York and New Jersey, both areas that experience significant amounts of snow and ice, continue to use raised tactile surfaces (O'Leary, Lockwood, Taylor, and Lavely, 1995).

The length of raised tactile surfaces in the path of travel is most effective when "beyond the average stride in length" so that pedestrians with visual disabilities can "sense it physically, understand its meaning, and react appropriately" before the hazard is encountered (U.S. Access Board, 1995). However, there is a definite trade-off between the high detectability of raised tactile surfaces for people with visual disabilities and ease of movement for people with mobility disabilities (O'Leary, Lockwood, Taylor, and Lavely, 1995).

Several researchers suggested limiting the width of detectable warnings to no more than that required to provide effective warning for people with visual impairments "given the moderately increased level of difficulty and decrease in safety" that raised tactile surfaces on slopes pose for people with physical disabilities (Bentzen, Nolin, Easton, Desmarais, and Mitchell, 1994; Rabelle, Zabihaylo, and Gresset, 1998; Hughes, 1995). Truncated domes that are uneven or too high can cause navigation difficulties for certain sidewalk users, including some bicyclists and in-line skaters. People who use walking aids and pedestrians wearing high heels might lose some stability along ramps covered with raised tactile surfaces. Neither manual nor powered wheelchair users appear to be at significant risk of instability when traveling on ramps with raised warnings (Hughes, 1995).

#### 4.4.2.2 Raised tactile surfaces used for wayfinding

Raised tactile surfaces also might provide wayfinding information to people with visual impairments, delineating paths across open plazas, crosswalks, and complex indoor environments such as transit stations. Wayfinding cues include raised tactile surfaces covered with bar patterns laid out in a path to indicate the appropriate walking direction, especially along routes where traditional cues such as property lines, curb edges, and building perimeters are unavailable. In Japan, bar tile has been used to direct pedestrians with visual impairments along transit stations and other heavily used pedestrian areas (Sawai, Takato, and Tauchi, 1998).

The city of Sacramento, California, uses a tactile guidestrip located in the center of some crosswalks to direct people with visual impairments across "irregular and complex" intersections. A San Francisco report recommended guidestrips at intersections with more than two streets, unusual crosswalks, right-turn lanes, diagonal crossings, exceptionally wide streets, and intersections with other unusual geometric designs (San Francisco Bureau of Engineering, 1996).

Hughes (1995) recommended that "mixed" patterns of both bar tiles and dome tiles be developed for use on curb ramps to provide orientation, as well as warning information, at intersections. However, research in Japan indicated that subjects who were blind had difficulty distinguishing between detectable surfaces with bars and dots or domes. In fact, confusion between warning and guiding tiles was suspected as the cause of several train platform accidents in Japan (Bentzen, Nolin, and Easton, 1994).

#### 4.4.2.3 Materials with contrasting sound properties

Adjacent surfacing materials that make different sounds when tapped by a cane can also serve as navigation cues (U.S. Access Board, 1985). Examples of materials with contrasting sound properties include concrete sidewalks next to textured metal, or paving tiles next to rubberized raised tactile surfaces. Materials with contrasting sound properties are used along curb ramps, crosswalks, and transportation platforms. Contrasting materials can also be colored differently from the surrounding paving material (Figure 4-31) or textured to provide visual and tactile information as well.

Materials used to provide sound contrasts should be appropriate to the given setting. For example, materials that degrade in harsh weather conditions or become slippery or hazardous when icy should not be installed outdoors but might be appropriate for indoor environments such as transit stations. People who use dog guides have a reduced opportunity to use sound cues, as described in this section.

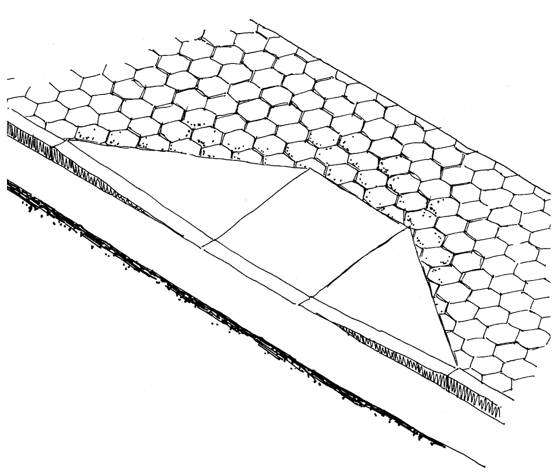


***Figure 4-31:***

***Colored stone sidewalks with concrete curb ramps have a detectable color change.***

#### 4.4.2.4 Grooves

Grooves are common and inexpensive to install, but there is little evidence that they can be detected or used by people with visual disabilities. One study indicated that concrete panels with various groove configurations had only a 9 to 40 percent detectability rate (Templer, Wineman, and Zimring, 1982). Cane users could confuse them with the grooves between sidewalk panels and cracks in the sidewalk.

Long-cane users typically travel using a “two-point touch” technique and only scrape the tip of the cane along the ground in the “constant contact” technique when more in-depth exploration of an area is warranted. However, in general, grooves can be detected only by a cane if the constant-contact technique is used to scan the environment. For this reason, grooves are generally ineffective to warn of a potentially hazardous situation such as an intersection. In addition, dirt, snow, ice, weeds, and other debris in the sidewalk environment are likely to collect in grooves and obscure any warning provided.

#### 4.4.2.5 Contrasting colors for people with low vision

Contrasting colors such as yellow paint against black asphalt can indicate a change in environment for people with low vision. Texture differences may also be detected by people with low vision. For example, although sidewalk grooves do not provide a significant tactile contrast, some people with low vision can detect groove patterns visually. The color contrast of visual warnings helps both sighted and partially sighted pedestrians to identify potentially hazardous areas. Colorized warnings are particularly useful for all pedestrians at night, when visual acuity and contrast sensitivity are impaired. Variations in surface coloring between the crosswalk and the street can also be used to mark the best path across an intersection. Reflective paint and building materials of contrasting colors are common methods used to provide visual warnings.

ADAAG Section 4.29.2 specifies that detectable warnings "shall contrast visually with adjoining surfaces, either light-on-dark, or dark-on-light." ADAAG Section A4.29.2 further specifies that "the material used to provide contrast should contrast by at least 70%" (ADAAG, U.S. Access Board, 1991). The effectiveness of ADAAG's recommendations for color contrast was evaluated by Bentzen, Lolin, and Easton (1994). The study concluded that the ADAAG 70 percent contrast recommendation "appears adequate to provide high visual detectability" but cautioned that minimum reflectance values should also be specified for the lighter surface to limit the effects of glare. The study also reported that surfaces colored safety yellow (ISO 3864) were most frequently chosen by low vision subjects as "most visually detectable" (Bentzen, Nolin, and Easton, 1994).

During the sidewalk assessments, visual warnings used on sidewalks were observed to include painted curb edges, tinted curb ramps, colored sidewalks (Figure 4-31), colorized raised tactile warnings, and painted crosswalks.

#### 4.4.2.6 Audible and vibrotactile pedestrian signals

Although people with visual impairments generally rely on traffic surges to determine when it is safe to cross an intersection, additional information about crossing conditions can be very useful when traffic sounds are sporadic or masked by ambient noise, the geometry of the intersection is irregular, or acoustics are poor. Accessible pedestrian signals can provide supplementary information, such as timing (when the signal cycle allows pedestrians to cross the street), wayfinding (which roads intersect at the junction), and orientation (the directional heading of each crosswalk). Accessible pedestrian signals are generally installed at complex intersections; intersections experiencing high volumes of turning traffic; major corridors leading to areas of fundamental importance such as post offices, courthouses, and hospitals; and places where people with visual impairments request them (Bentzen, 1998).

A number of different types of accessible pedestrian signals have been developed and were analyzed in a 1998 synthesis by B.L. Bentzen. These include audible broadcast, tactile, vibrotactile, and receiver-based systems, many of which may be integrated with each other to provide additional sources of information.

Audible traffic signals (ATSs) include devices that emit audible sounds when the signal permits pedestrians to cross. ATSs "comprise a warning system that alerts the pedestrian to the onset of a green light" (Hall, Rabelle, and Zabihaylo, 1994). Simple systems use a consistent sound to indicate when the signal has changed. More complex systems use one sound pattern to indicate north/south streets, and another sound to indicate east/west streets, providing both timing and orientation information. Others broadcast prerecorded speech messages telling the name of the street being crossed and the status of the signal cycle (Bentzen, 1998). Street crossings that can be negotiated easily by people with visual impairments are preferred to ATS systems. These systems should be installed only "as a last resort, and only when the installation will guarantee the safety of the visually impaired pedestrian" (Hall, Rabelle, and Zabihaylo, 1994).

Alternating ATS systems, in which speakers on either side of the street alternate indicator sounds, provide alignment assistance for pedestrians with visual impairments. “An alternating signal counters the masking effect of the nearby signal [and] promotes more accurate alignment before crossing and straight-line travel throughout the crossing” (Hall, Rabelle, and Zabihaylo, 1994). Alternating ATS systems result in a straighter line of travel because they allow people with visual disabilities “to align themselves more accurately before and during the crossing. . . .” (Hall, Rabelle, and Zabihaylo, 1994).

Audible information is also useful to identify pedestrian-actuated control signals. Audible pedestrian signals that alert pedestrians to the existence and location of the signal actuator include push-button devices that emit sounds. Tactile pedestrian signals include raised arrows on the signal actuator that indicate which street is controlled by the push button. Tactile pedestrian signals can also provide map information, using raised dot and line symbols to indicate details such as the number of lanes to be crossed, the direction of traffic in each lane, and whether there is a median (Bentzen, 1998).

Vibrotactile traffic devices also can provide information about the presence and location of a pedestrian-actuated signal. In vibrotactile systems, the push-button apparatus will vibrate while pedestrians are permitted to cross. Such systems allow deaf-blind pedestrians to identify the WALK interval and can be installed at medians to prevent signal overlap when audible broadcast signals are in effect (Bentzen, 1998).

Receiver-based systems provide audible or other accessible information only when triggered by a nearby pedestrian-carried receiver. The Talking Signs® system, for example, uses transmitters that emit infrared beams containing prerecorded speech information. The speech message can label streets, transit kiosks, and other areas. The transmitters can be mounted on traffic poles, buildings, and other significant locations. Pedestrians using the system carry a receiver that picks up the infrared signals and plays them back as audible messages. This system provides both orientation and wayfinding information. The user can hone in on the transmitter’s location because the messages are played most clearly when the receiver is oriented directly toward the transmitter (Bentzen, 1997, in Blasch et al.)

#### 4.4.2.7 ADAAG requirements for detectable warnings

When ADAAG was first approved in 1991, it contained requirements for detectable warnings at curb ramps, transit platforms, reflecting pools, and hazardous vehicular areas. ADAAG defined a detectable warning as “a standardized surface feature built in or applied to walking surfaces or other elements to warn visually impaired people of hazards on a circulation path.” Detectable warnings on walking surfaces were required to be truncated domes with a diameter of 23 mm (0.9 in.), a height of 5 mm (0.2 in.) and a center-to-center spacing of 60 mm (2.35 in.). In addition, detectable warnings had to offer a strong visual contrast to adjacent pedestrian surfaces and had to be an integral part of the walking surface (ADAAG, U.S. Access Board, 1991).

On April 1, 1994, the ADAAG scoping provisions for detectable warnings at curb ramps, hazardous vehicular areas, and reflecting pools were initially suspended until July 1996, and were later extended until July 26, 1998, and 2001, while the requirements for detectable warnings at transit platforms remained in effect. The requirement was initially suspended to allow the U.S. Access Board, the US DOJ, and the US DOT to consider the results of additional research on the need for and safety effects of detectable warnings at vehicular–pedestrian intersections.

The study found that, although detectable warnings were not shown to be needed at all curb ramp locations, they did provide "the blind traveler with one potential additional cue that is especially useful in a low-cue environment." Many nonvisual cues used to detect streets are intermittent, such as the sound of traffic. Detectable warning surfaces provide a permanent cue that identifies the transition between the sidewalk and the street. The study concluded that "the effectiveness of detectable warning surfaces on curb ramps depends greatly on other aspects of the design of the intersection, as well as on such social factors as the density of traffic and the skills of the traveler." The study recommended the installation of a 2-foot-wide strip of detectable surface at the curb line as an alternative to covering the entire surface of the ramp (Hauger et al., 1996).

### 4.4.3 Driveway Crossings

Driveway crossings permit cars to cross the sidewalk and enter the street, and they consist of the same components found in curb ramps. It is the driver's responsibility to yield to the pedestrian at the driveway–sidewalk interface.

Intersections of driveways and sidewalks are the most common locations of severe cross-slopes for sidewalk users. Some inaccessible driveway crossings have cross-slopes that match the grade of the driveway because a level area is not provided for the crossing pedestrian. This type of crossing can be very difficult for people who use wheelchairs or walking aids (Figure 4-32).

Rapid changes in cross-slope usually occur at driveway flares and are most problematic when they occur over a distance of less than 0.610 m (24 in), or the approximate length of a wheelchair wheelbase. As the wheelchair moves over the surface of a severely warped driveway flare, it will first balance on the two rear wheels and one front caster. As the wheelchair continues to move forward, it then tips onto both front casters and one rear wheel (Figure 4-32). Rapidly changing cross-slopes also can cause wheelchair users to lose directional control, veer downhill toward the street, and potentially tip over. This phenomenon can also cause pedestrians who use walking aids to stumble. For more information on rate of change of cross-slope, refer to Section 4.3.2.

Well-designed driveway crossings eliminate severe cross-slope along the path of travel. Driveway crossings designed along setback sidewalks can easily be made accessible because the setback permits designers to maintain a level path of travel along the sidewalk. The driveway ramp then resumes sloping at the setback (Figure 4-33).

***Figure 4-32:***

***Driveway crossings without landings confront wheelchair users with severe and rapidly changing cross-slopes at the driveway flare.***

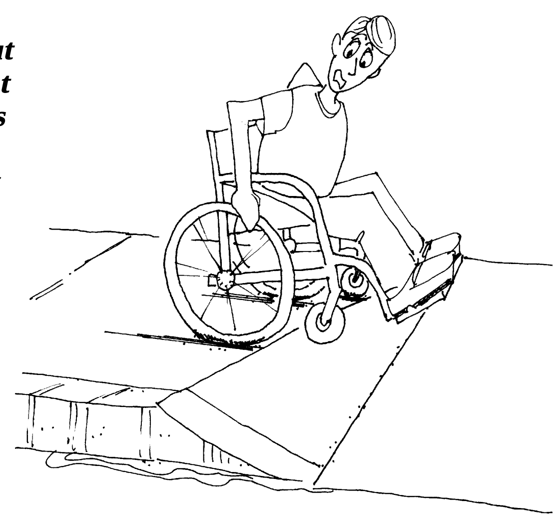
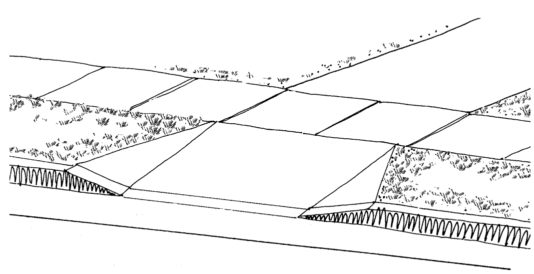


***Figure 4-33:***

***When sidewalks have a planter strip, the ramp of the driveway does not interfere with a pedestrian's path of travel.***



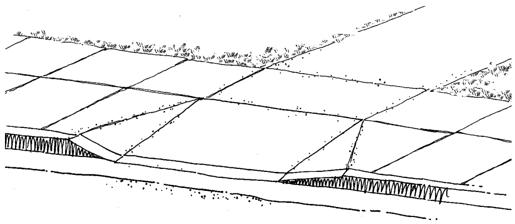


***Figure 4-34:***

***On wide sidewalks, there is enough room to provide a ramp for drivers and retain a level landing for pedestrians.***

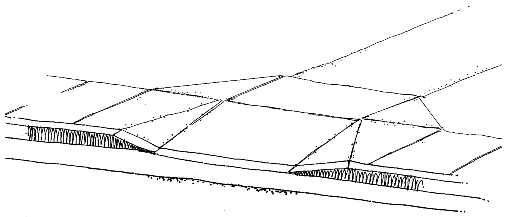


***Figure 4-35:***

***Jogging the sidewalk back from the street provides a level landing for pedestrians on narrow sidewalks.***

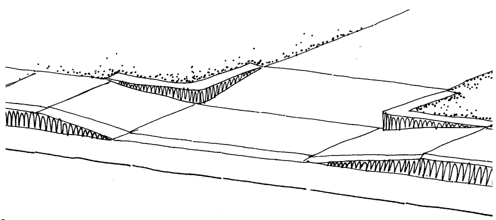


***Figure 4-36:***

***Although parallel driveway crossings provide users with level landings, users continuing on the sidewalk are forced to negotiate two ramps.***

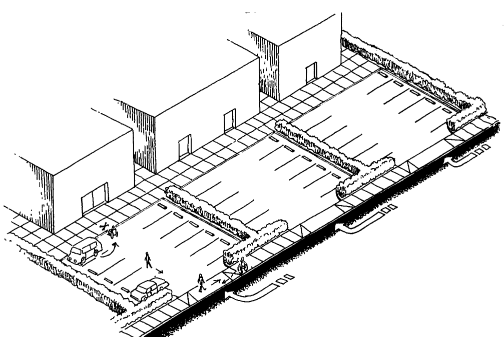


***Figure 4-37:***

***Inaccessible sidewalk caused by many individual parking lots.***

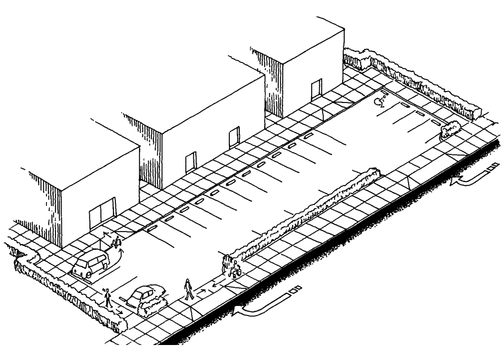


***Figure 4-38:***

***Improved accessibility created by combining parking lots and reducing the number of entrances and exits.***

Wide sidewalks can be designed similar to sidewalks with a setback if the upper portion of the sidewalk is leveled for pedestrians and the bottom portion is sloped for automobiles (Figure 4-34).

A level landing area can be achieved on narrow sidewalks if the sidewalk is jogged back from the street as it crosses the driveway (Figure 4-35). Purchasing additional land to jog the sidewalk back should be strongly considered when there is not enough space for a level sidewalk.

Similar to a parallel curb ramp, a parallel driveway crossing provides a level landing by lowering the sidewalk to the grade of the street (Figure 4-36). This design is preferable to the severe cross-slopes at some driveway crossings, but it is not as easy to negotiate as setback and wide sidewalk designs. With this type of crossing, drivers assume that they can speed up on the level portion next to the street. In addition, the parallel ramp can produce steep grades on both sides of the driveway and initiate drainage problems on the landing.

Commercial districts with front parking between the sidewalk and the buildings are often designed with a series of individual lots with individual entrances and exits (Figure 4-37). This design increases the number of driveway crossings and forces pedestrians to encounter automobiles repeatedly. If the driveway crossings do not have level landings, people with mobility disabilities must also repeatedly negotiate severe cross-slopes. To improve access for all pedestrians, including pedestrians with mobility disabilities, individual parking lots should be combined to reduce the number of entrances and exits. The remaining driveway crossings should be retrofitted to include level landings (Figure 4-38).

### 4.4.4 Medians and Islands

Medians and islands help pedestrians cross streets by providing refuge areas that are physically separated from the automobile path of travel. A *median* separates opposing lanes of traffic. An *island* is a protected spot within a crosswalk for pedestrians to wait to continue crossing the street or to board transportation such as a bus. Medians and islands are useful at irregularly shaped intersections, such as where two roads converge into one (Earnhart and Simon, 1987).

Medians and islands reduce the crossing distance from the curb and allow pedestrians to cross during smaller gaps in traffic. Examples of cut-through medians and ramped and cut-through islands are shown in Figure 4-39 and 4-40. Medians and islands are useful to pedestrians who are unable to judge distances accurately. Medians and islands also help people with slow walking speeds cross long intersections with short signal cycles. Because medians and islands separate traffic into channels going in specific directions, they require crossing pedestrians to watch for traffic coming in only one direction.

According to ADAAG, a raised island or median should be level with the street or have curb ramps at all sides and a level area 1.220 m (48 in) long in all directions. If a cut-through design is used, it should be at least 0.915 m (36 in) wide. Cut-through medians are easier for wheelchair users and other people with mobility impairments to negotiate than ramps. In addition, the edge of a cut-through can provide directional information to people with visual impairments. However, if the cut-through is too wide, people with visual impairments might not detect the presence of a median or island. For this reason, the width of the cut-through should be limited to ensure detection by people with visual impairments. A detectable warning on the surface of the cut-through will also improve detectability.

### 4.4.5 Crosswalks

Crosswalks are a critical part of the pedestrian network. A crosswalk is defined as "the portion of a roadway designated for pedestrians to use in crossing the street" and may be either marked or unmarked (Institute of Transportation Engineers, Technical Council Committee 5A-5, 1998).

Marked crosswalks are most effective when they can be identified easily by motorists. However, many pedestrians,

***Figure 4-39:***

***Cut-through corner island and center median***
***(based on OR DOT, 1995).***

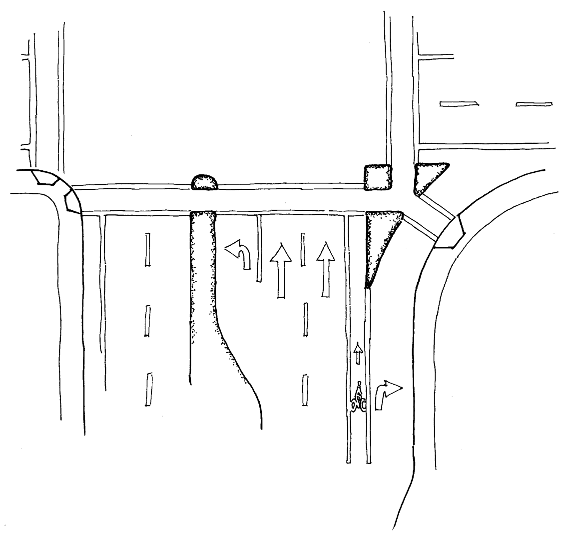


***Figure 4-40:***

***Ramped corner island and cut-through median***
***(based on OR DOT, 1995).***

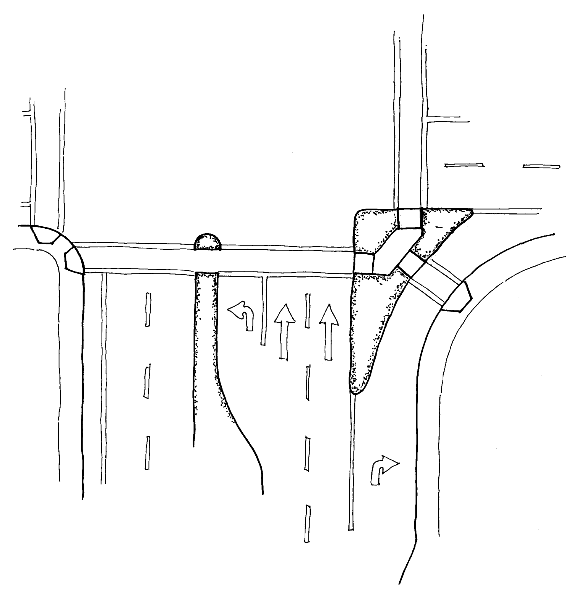


***Figure 4-41:***

***Two horizontal lines are the most common crosswalk markings.***

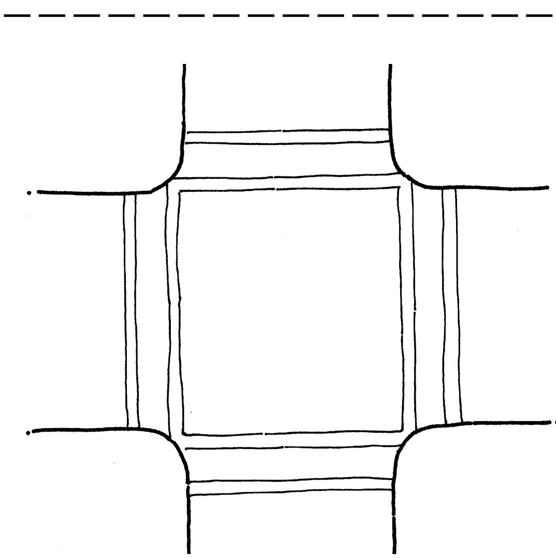


***Figure 4-42:***

***A ladder design was found to be the most visible type of pedestrian crosswalk marking.***

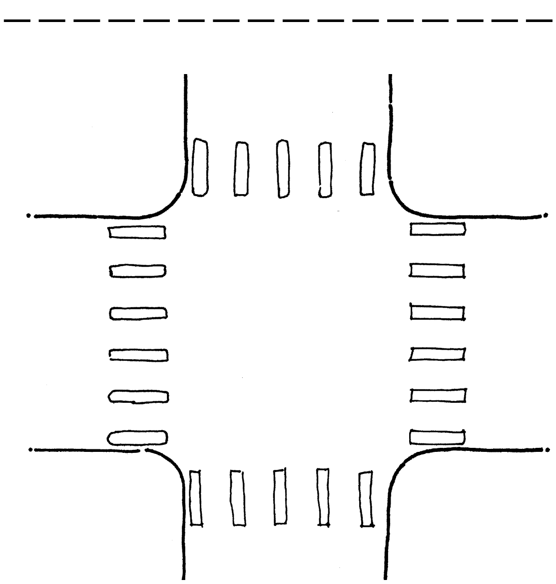
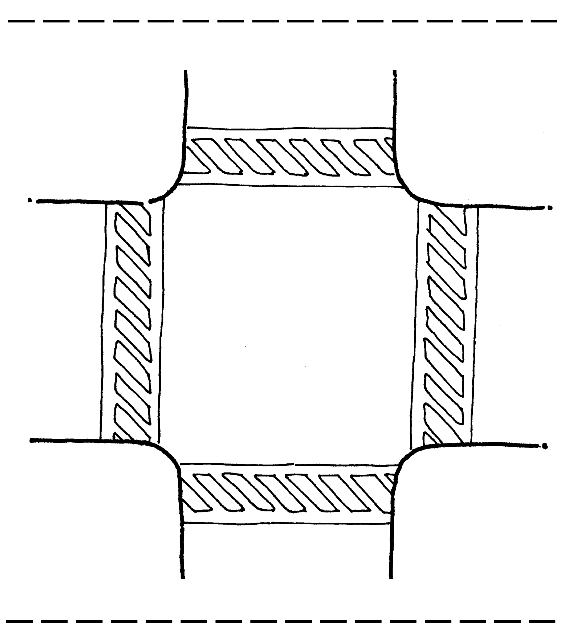


***Figure 4-43:***

***Diagonal markings enhance visibility.***



including pedestrians with low vision, benefit from clearly marked crosswalks. For this reason, proposed Section 14 (1994) required marked crossings to be "delineated in materials or markings that provide a visual contrast with the surface of the street" (U.S. Access Board, 1994b). Most State DOTs follow the *Manual of Uniform Traffic Control Devices* (MUTCD) guidelines for marking crosswalks. Although the MUTCD does permit some variations for additional visibility, the basic specifications call for solid white lines not less than 150 mm (6 in) marking both edges of the crosswalk and spaced at least 1.830 m (72 in) apart (US DOT, 1988) (Figure 4-41). A study by Knoblauch, Testin, Smith, and Pietrucha (1988) found the ladder design, shown in Figure 4-42, to be the most visible type of crosswalk marking for drivers. Diagonal striping can also enhance the visibility of a pedestrian crossing (Figure 4-43).

When a diagonal curb ramp is used at an intersection, a 1.220-m (48-in) clear space should be provided to allow ramp users enough room to maneuver into the crosswalk.

In some situations, marked crosswalks might not be enough to ensure pedestrian safety. For example, at high-speed intersections without traffic signals, drivers often cannot perceive a marked crosswalk quickly enough to react to pedestrians in the roadway. This problem is compounded by the fact that "pedestrians may 'feel safer' within a marked crosswalk and expect motorists to act more cautiously" (Institute of Transportation Engineers, Technical Council Committee 5A-5, 1998). Some agencies around the United States consider that removing crosswalk markings improves pedestrian safety. Alternative treatments such as electronically activated crosswalks, pedestrian-actuated traffic controls, flashing traffic signals, light guard flashing crosswalks, traffic calming measures, raised crosswalks, and traffic signals are also being used. FHWA studies are currently being conducted to determine if these measures provide safer crossing for pedestrians.

Most marked crosswalks observed during the sidewalk assessments were marked with paint. Others were built with contrasting materials such as red brick inside the crosswalk, bordered with gray concrete. Contrasting textures can provide tactile guidance for people with visual impairments, as well as visible colorized warnings.

### 4.4.6 Crossing Times

People's walking pace and starting pace varies depending on their personal situation. Older pedestrians might require longer starting times to verify that cars have stopped. They also might have slower reaction times and slower walking speeds. Powered wheelchair users and manual wheelchair users on level or downhill slopes might travel faster than other pedestrians. But on uphill slopes, manual wheelchair users might have slower travel speeds. At intersections without audible pedestrian signals, people with visual impairments generally require longer starting times because they rely on the sound of traffic for signal-timing information.

The *AASHTO Green Book* indicates that "average walking speeds range from 0.8 to 1.8 m/s." The MUTCD assumes an average walking speed of 1.220 m/s (4 ft/s). However, research on pedestrian walking speeds has demonstrated that more than 60 percent of pedestrians walk more slowly and that 15 percent of pedestrians walk at less than 1.065 m/s (3.5 ft/s) (Kell and Fullerton, 1982). The *AASHTO Green Book* recommends a walking rate of 1.0 m/s (39 in/s) for older pedestrians (AASHTO, 1995).

Pedestrians of all mobility levels need to cross intersections. However, when crossing times accommodate only people who walk at or above the average walking speed, intersections become unusable for people who walk at a slower pace. To accommodate the slower walking speeds of some pedestrians, transportation agencies should consider extending their pedestrian signal cycles. Signal timing should be determined on a case-by-case basis, although extended signal cycles are strongly recommended at busy intersections that are unusually long or difficult to negotiate.

### 4.4.7 Pedestrian-Actuated Traffic Controls

Pedestrian-actuated traffic controls require the user to push a button to activate a walk signal. According to the MUTCD, pedestrian-actuated traffic controls should be installed when a traffic signal is installed under the Pedestrian Volume or School Crossing warrant, when an exclusive pedestrian phase is provided, when vehicular indications are not visible to pedestrians, and at any established school crossings with a signalized intersection (US DOT, 1988). If the intersection has a median, a button should be added to the median and both corners.

Unfortunately, pedestrian-actuated control signals are often inaccessible to people with mobility impairments and people with visual impairments. To be accessible to wheelchair users and people with limited mobility, pedestrian-actuated traffic controls need to be located as close as possible to the curb ramp without reducing the width of the path. They also need to be mounted low enough to permit people in wheelchairs to reach the buttons. ADAAG does not specify a height for pedestrian-actuated control systems. However, ADAAG Section 4.10.3 states that elevator buttons should be located no higher than 1.065 m (42 in) (ADAAG, U.S. Access Board, 1991).

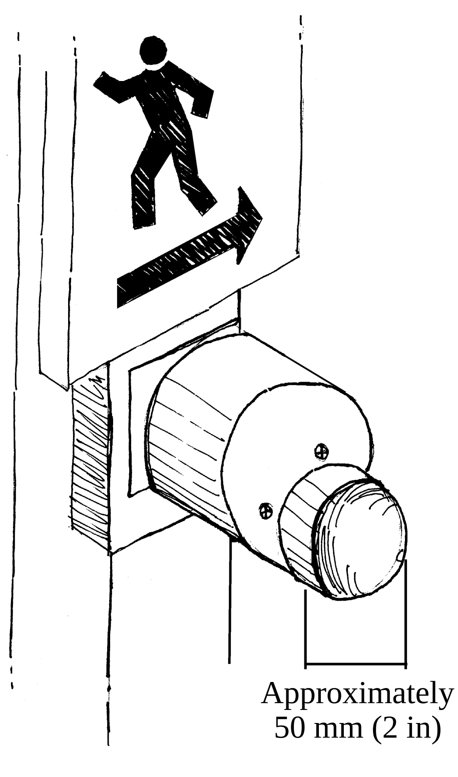
The size and type of the button also affect the accessibility of the control. Larger raised buttons are easier for people with visual impairments to identify (Figure 4-44). According to proposed Section 14 (1994), buttons should be raised above or flush with their housings and be at least 50 mm (2 in) in the smallest dimension (U.S. Access Board, 1994b).

Pedestrian-actuated control buttons require more force to operate than most indoor buttons. However, people with limited hand strength or dexterity might be able to exert only a limited amount of force. To address this need, proposed Section 14 (1994) recommended that the force required to activate controls should not be greater than 22.2 N (5 lbf) (U.S. Access Board, 1994b).

People with visual impairments might be at a disadvantage at intersections with pedestrian-actuated crossing controls if they are unaware that they need to use a control to initiate a pedestrian crossing signal. At an intersection with a pedestrian-actuated control button, a person with a visual impairment must detect whether a signal button is present, then push it and return to the curb to align for the crossing. This process might require several signal cycles if the button is not located within easy reach of the curb edge. People with visual impairments can confirm the presence of and locate pedestrian-actuated crossing controls more easily if the controls emit sounds and/or vibrations. To address the need for pedestrian-actuated control signals that are accessible to people with visual impairments, TEA-21 provides funding for “the installation, where appropriate, and maintenance of audible traffic signals and audible signs at street crossings” (TEA-21, 1998). Accessible pedestrian signals that accommodate people with visual impairments are discussed in Section 4.4.2.6 of this report.

***Figure 4-44:***

***A large, easy-to-press button makes pedestrian-actuated traffic controls more usable for people with limited hand strength and dexterity.***




Many varieties of controls were observed during the sidewalk assessments. The most accessible were relatively large and could be activated with little force. Those that were least accessible were small, required significant force to activate, and were located far from the logical crossing point. Some pedestrian-actuated traffic controls were positioned so that users standing at the edge of the sidewalk had to walk around traffic poles to reach the control button. In other instances, obstacles such as newspaper stands were placed in front of the controls, blocking access to the trigger mechanism. Intersections with awkwardly placed pedestrian-actuated controls can be made more accessible by moving the control to a more easily reached location or altering the signal timing to allow pedestrians to realign themselves for a crossing before the light changes.

### 4.4.8 Midblock Crossings

Midblock crossings are pedestrian crossing points that do not occur at intersections. They are often installed in areas with heavy pedestrian traffic to provide more frequent crossing opportunities. For midblock crossings to be accessible to people with mobility impairments, a curb ramp needs to be installed at both ends of the crossing along a direct line of travel. If the curb ramps are offset, pedestrians who rely on the curb ramps are forced to travel in the street.

For midblock crossings to be accessible to people with visual impairments, they need to be detectable. At midblock crossings, pedestrians with visual impairments do not have the sound of parallel traffic available to identify a midblock crossing opportunity. If a traffic signal is installed, an audible indicator that provides timing information should also be included. Audible or vibrotactile information is effective in alerting people with visual impairments of a midblock crossing.

Midblock crossings spanning multiple lanes can be difficult for some pedestrians to cross. In these situations, curb extensions can be effective in reducing crossing times and increasing visibility between pedestrians and motorists (Figure 4-45). A median is another effective method to reduce crossing distances.

### 4.4.9 Sight Distances

Sight distance is defined as “the distance a person can see along an unobstructed line of sight” (University of North Carolina, Highway Safety Research Center, 1996). Adequate sight distances between pedestrians and motorists increase pedestrian safety. Motorists also need appropriate sight distances to see traffic signals in time to stop. Vertical sight distance can be important for drivers of high vehicles such as trucks and buses, whose sight lines might be blocked by trees or signs (ibid.). Although bollards, landscaping, parking, benches, or bus shelters make pedestrian areas more inviting by calming traffic and providing amenities, they can also clutter the environment and block sight lines between motorists and pedestrians waiting to cross the intersection.

Trimming vegetation, relocating signs, and hanging more than one sign or traffic signal on one arm pole where permitted by MUTCD can improve sight distances at corners. Parked cars near the intersection or midblock crossing can also reduce sight distances (Figure 4-46). Installing curb extensions physically deters parking at intersection corners and improves the visibility of pedestrians, as

***Figure 4-45:***

***Curb extensions at midblock crossings help reduce crossing distance.***

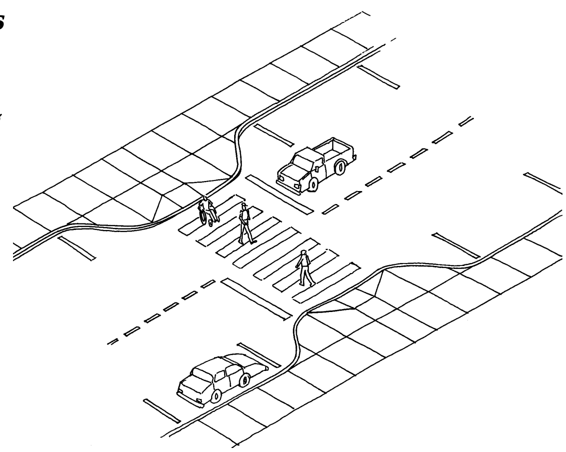
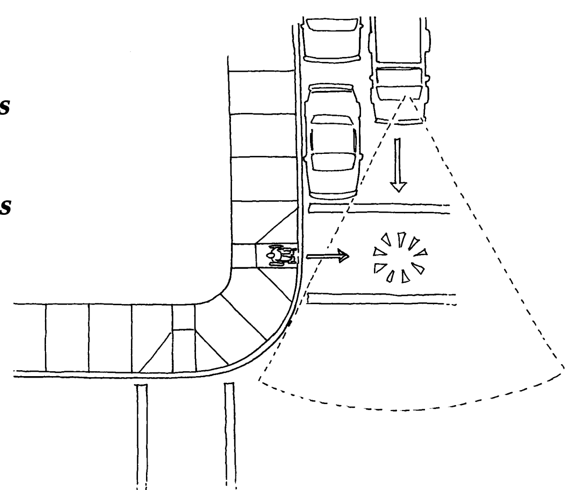


***Figure 4-46:***

***Sight line obstructed by parked cars prevents drivers from seeing pedestrians starting to cross the street.***



shown in Figures 4-47 and 4-48. Curb extensions can also increase the angle at which pedestrians meet motor vehicles, improving the visibility of both (OR DOT, 1995). In addition, curb extensions shorten crossing distances and provide sidewalk space for curb ramps with landings.

***Figure 4-47:***

***Partial curb extensions improve visibility between pedestrians and motorists.***

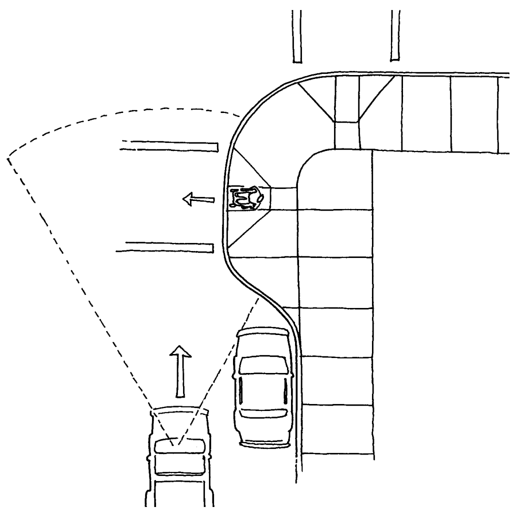


***Figure 4-48:***

***Full curb extensions improve visibility between pedestrians and motorists.***

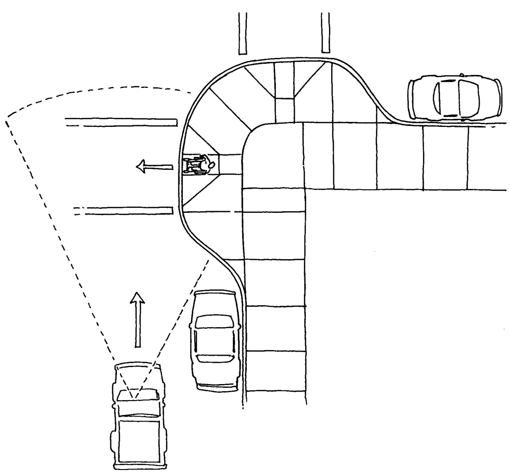
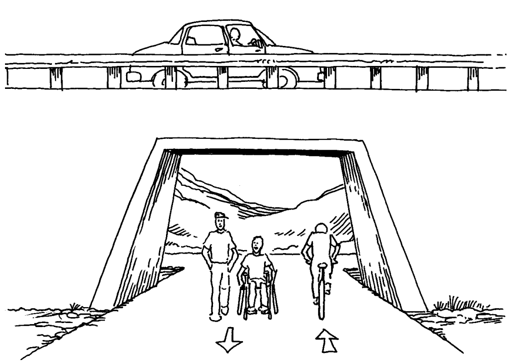


***Figure 4-49:***

***Pedestrian and biker underpass.***



### 4.4.10 Grade-Separated Crossings

Grade-separated crossings are facilities that allow pedestrians and motor vehicles to cross at different levels. Some grade separated crossings are very steep and are difficult for people with mobility impairments to negotiate. In addition, grade-separated crossings are extremely costly to construct and are often not considered pedestrian-friendly because pedestrians are forced to travel out of their way to use the underpass or overpass. The effectiveness of a grade-separated crossing depends on whether or not pedestrians perceive that it is easier to use than a street crossing (Bowman, Fruin, and Zegeer, 1989).

Examples of grade-separated crossings include the following (Institute of Transportation Engineers Technical Council Committee 5A-5, 1998):

- *Overpasses* — bridges, elevated walkways, and skywalks or skyways
- *Underpasses* — pedestrian tunnels and below-grade pedestrian networks

Figure 4-49 illustrates a pedestrian underpass.

The needs of pedestrians should be a high priority at grade-separated crossings. If designed correctly, grade-separated crossings can reduce pedestrian-vehicle conflicts and potential accidents by allowing pedestrians to avoid crossing the path of traffic. They can also limit vehicle delay, increase highway capacity, and reduce vehicle accidents when appropriately located and designed. Grade-separated crossings can improve pedestrian safety, reduce travel time, and serve to maintain the continuity of a neighborhood in which high-traffic roads run through residential areas (University of North Carolina, Highway Safety Research Center, 1996).

Grade-separated crossings are most efficient in areas where pedestrian attractions such as shopping centers, large schools, recreational facilities, parking garages, and other activity centers are separated from pedestrian generators by high-volume and/or high-speed arterial streets.

Well-designed grade-separated crossings minimize slopes, feel open and safe, and are well lit. Minimizing the slope of a grade-separated crossing is often difficult because a significant rise, generally from 4.3 to 5.5 m (14 to 18 ft), must be accommodated. Inaccessible grade-separated crossings should not be constructed. In some situations, elevators can be installed to accommodate people with mobility impairments.

Underpasses might invite crime if insufficiently lit and seldomly traveled. Underpasses can also be more expensive to install than other pedestrian facilities because a tunnel must be dug and utility lines relocated. Tunnels are more inviting to use when they are brightened with skylights or artificial lighting and are wide and high enough to feel open and airy (ibid.).

### 4.4.11 Roadway Design

Sidewalk accessibility is intimately affected by the design of roads. Factors affecting roadway safety and accessibility for pedestrians include sight distance, design speed, location, cross-slope, grade, and the functional class of the road. Although some States have their own guidelines, most roadway designers rely on the *AASHTO Green Book* for street development specifications. The *AASHTO Green Book* recognizes several general factors as important to the functionality of public rights-of-way, including the grade of the road, cross-slopes, traffic control devices, curbs, drainage, the road crown, and roadway width (Table 4-1).

***Table 4-1:***

***Grade, Cross-Slope, and Curb Height Guidelines by Functional Class of Roadway***
***(based on information contained in AASHTO, 1995)***

| Road Type | Maximum Grade (%)[1] Level/Rolling/Mountain | Cross-Slope[3] (%) | Curb Height (mm) | Sidewalk Coverage |
|---|---|---|---|---|
| Urban local | Consistent with terrain | 1.5–6.0[4] | 100–225 | Commercial — both sides |
| | <15.0/<8.0[2] | | | Residential — at least one side |
| Rural local | 8.0/11.0/16.0 | 1.5–6.0[4] | n/a | n/a[5] |
| Urban collector | 9.0/12.0/14.0 | 1.5–3.0 | 150–225 | Same as Urban local |
| Rural collector | 7.0/10.0/12.0 | 1.5–3.0 | n/a | n/a[5] |
| Urban arterial | 8.0/9.0/11.0 | 1.5–3.0 | 150–225 | n/a[5] |
| Rural arterial | 5.0/6.0/8.0 | 1.5–2.0 | n/a | n/a[5] |
| Recreational | 8.0/12.0/18.0 | n/a | n/a | n/a[5] |

Chart does not include figures for freeways or divided arterials, which are not designed for pedestrians and are not built with sidewalks.

[1] The lower the maximum speed permitted on the road, the steeper the grade is permitted to be. The numbers listed in the chart represent the lowest road speeds indicated in the *AASHTO Green Book*.

[2] Residential/commercial or industrial.

[3] The numbers listed in the chart indicate what the cross-slope should generally be for proper drainage.

[4] Cross-slopes ranging from 3.0 to 6.0 percent should be used only for low surface types such as gravel, loose earth, and crushed stone.

[5] Sidewalks are still needed, even though the *AASHTO Green Book* does not specify guidelines for sidewalk coverage along this road.

The functionality of a roadway should be balanced with the needs of pedestrians. Too often, roadway design prioritizes the needs of motorists, and pedestrians are put at risk. Pedestrians would be well accommodated if they received the same design considerations as drivers. When a sidewalk is included along a roadway, it must be accessible according to the ADA regulations. To accomplish this task, roadway designers must understand how roadway designs impact pedestrians and prioritize accessible road development.

The manner in which roads are maintained also impacts pedestrians. Asphalt, an economical and durable material, is used to pave most roads. In the past, repairing damage to asphalt roads typically entailed overlaying the existing pavement with more asphalt. Over time, the asphalt layers build up the roadway crown and can create steep slopes on either side of the centerline. These slopes can be difficult for crossing pedestrians to negotiate (Figure 4-50) and create rapidly changing grades at curb ramps. Because used asphalt can now be recycled, it is currently more common for roads to be milled before they are resurfaced. To improve accessibility, roads should always be milled before being resurfaced. The same amount of asphalt to be added to a road should be milled away prior to any resurfacing project. Milling should be completed from gutter to gutter to avoid crowning (Figure 4-51). In addition, because the US DOJ has indicated that "resurfacing beyond normal maintenance is an alteration," accessibility improvements such as curb ramp installations must also be incorporated into road resurfacing projects (US DOJ, 1994).

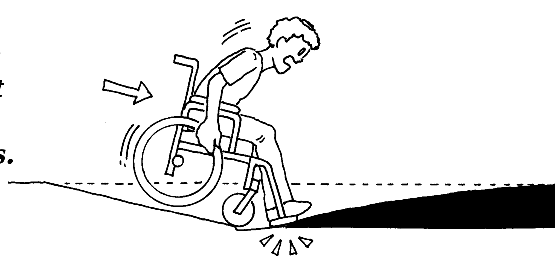


***Figure 4-50:***

***When roads are not milled, layers of asphalt build up and make the crossing difficult for wheelchair users and others.***

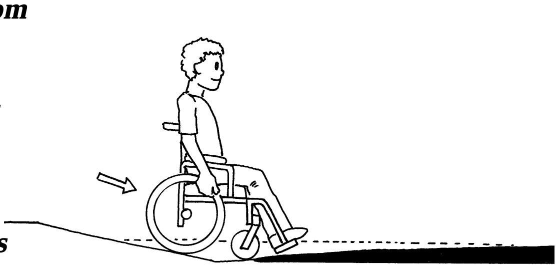


***Figure 4-51:***

***Milling roads from gutter to gutter prevents rapidly changing grades and makes intersections easier for wheelchair users to negotiate.***

### 4.4.12 Drainage

Sidewalks and sidewalk elements, such as curb ramps and driveway crossings, must be designed to provide efficient drainage as well as good access. Sidewalks provide the main conduit for draining the walking surface, adjacent properties, and, in some cases, the roadway. Sidewalks with poor drainage can accumulate precipitation that is not only a nuisance but might impede access or endanger the health, safety, and welfare of all pedestrians. For example, poorly drained sidewalks in cold climates can freeze over with ice and cause a hazard for pedestrians. Poorly drained sidewalks also permit the accumulation of silt and debris, further impeding access. The *AASHTO Green Book*, adopted by most States, provides slope ranges based on street type (Table 4-1).

Local topography and weather conditions also affect how steeply sidewalks, gutters, and roads should be sloped to provide adequate drainage. According to the *AASHTO Green Book*, a cross-slope between 1.5 to 2.0 percent provides effective drainage on paved surfaces in most weather conditions (AASHTO, 1995).

Gutters are generally sloped more steeply than the roadway to increase runoff velocity. Concrete gutters are smoother, offer less resistance to runoff, and are more water-resistant than asphalt, but they are also more expensive to install. According to the *AASHTO Green Book*, gutters should have "a cross-slope of 5 to 8 percent to increase the hydraulic capacity of the gutter section" (AASHTO, 1995). ADAAG specifies a 5 percent maximum slope at gutters (ADAAG, U.S. Access Board, 1991). This provision helps prevent wheelchair users from hitting their footrests on the ramp or gutter and potentially being thrown forward out of their wheelchairs. Section 4.3.1 contains additional information on rate of change of grade and gutter design.

A wider gutter can be used to drain larger volumes of water without increasing the slope experienced by curb ramp users. However, widening the gutter might require the purchase of additional right-of-way. According to the *AASHTO Green Book*, gutters formed in combination with curbs should range from 0.3 m to 1.8 m (12 in to 71 in) wide (AASHTO, 1995).

Barrier curbs are higher than other types of curbs to discourage vehicles from leaving the roadway (AASHTO, 1995). The height and more perpendicular face of barrier curbs also help sidewalks from being inundated in areas prone to flooding. High curbs can also cause curb ramps to be longer and occupy more sidewalk or street space. These restrictions make it more difficult to install accessible ramps on narrower sidewalks.

Storm drains and catch basins are normally placed where they will intercept surface water runoff. Installing a curb ramp at a point of strategic runoff interception can compromise effective drainage. Regrading the section of road or curb ramp location to alter drainage patterns can resolve some situations in which drainage concerns conflict with accessibility requirements. Ideally, inlets should be placed uphill of crossings or curb ramps to drain water before it can puddle where pedestrians are crossing. In locations with heavy rainfall, more frequent drainage inlets, more strategic placement of inlets, and basin pickups will also reduce the frequency of puddles.

### 4.4.13 Building Design

Newly constructed buildings are required to be accessible under Titles II and III of the ADA. Building entrances must be at grade with the sidewalk or provide accessible ramps to bridge elevation changes between the building and the street. In some existing facilities, a significant elevation difference exists between the street and the finished floor elevation (FFE) of the building. Inaccessible building entrances with stairs or sidewalks with significant cross-slopes are often the result (Figures 4-52 and 4-53).

Factors influencing the FFE of a building can include zoning ordinances, building

***Figure 4-52:***

***Stairs bridging low street elevation and high finished-floor elevation prevent wheelchair access into the building.***

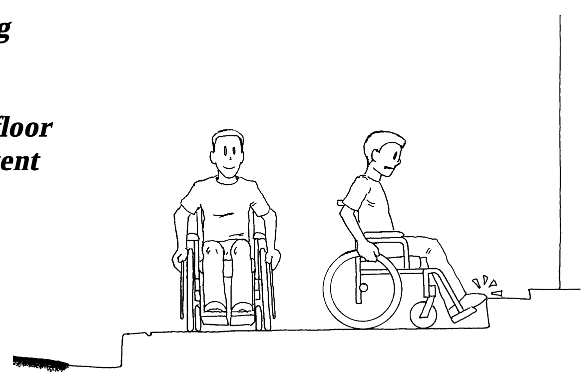
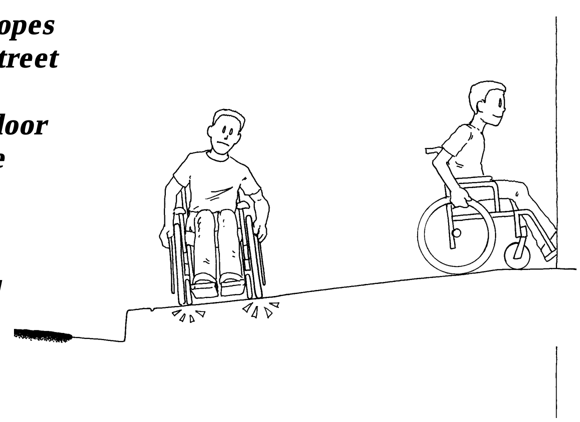


***Figure 4-53:***

***Steep cross-slopes bridging low street elevation and high finished-floor elevation make the sidewalk difficult for wheelchair users to travel across.***



codes, and conditions such as geologic formations, topography, and the hydrologic makeup of an area. The requirements of other agencies, including the Federal Emergency Management Agency (FEMA), the Army Corps of Engineers, and the Federal Aviation Administration, as well as wetland laws, can also influence the FFE of buildings in a given region. For example, FEMA requires communities located within flood plains to elevate buildings above expected water rise levels. Such safety recommendations are commonly included in local building codes. Insurance companies might demand higher FFEs if coverage for flood damage is desired.

When sidewalk design is not given sufficient emphasis by transportation planning and review processes, sidewalk designers are left to bridge the gap between building and street elevations. Creative solutions include providing a level area and sloping the edge of the path, or raising the curb to level the sidewalk (Figures 4-54 and 4–55).

***Figure 4-54:***

***A level area at least 0.915 m (36 in) wide improves access when there is a low street elevation and high finished-floor elevation.***

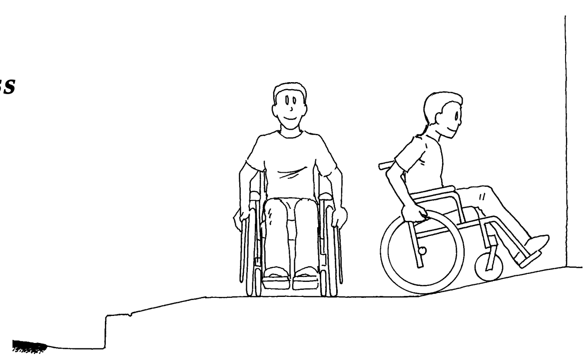
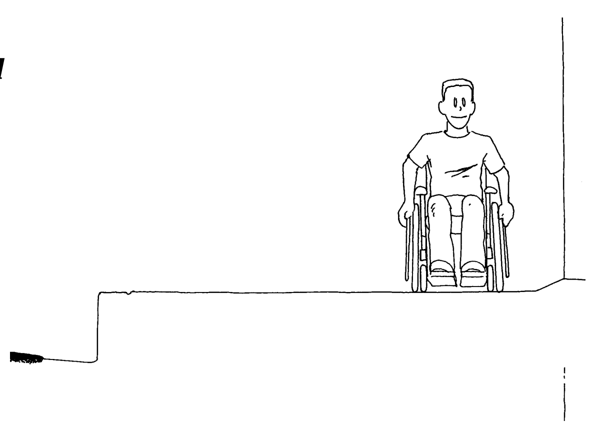


***Figure 4-55:***

***A higher curb provides a level pathway but might increase the slope of curb ramps if the sidewalk is narrow.***



Road, sidewalk, and building designers should coordinate their efforts to ensure that accessible sidewalks are developed in new construction and alterations. Good review processes, including a variety of interest groups, can ensure that construction plans for accessible sidewalks are implemented.

Transportation agencies differ greatly in the degree to which they address pedestrian facilities. Some areas permit developers to exclude sidewalk plans from the review of the overall construction plan and create inaccessible pathways and noncompliant buildings, while others make consideration of sidewalk plans mandatory. The disparity in the types of requirements builders and developers must meet was illustrated in a 1995 National Association of Home Builders (NAHB) survey. The survey revealed that, while 94 percent of builders and developers had to obtain building permits, only 36 percent were required to undergo plan checking, and only 19 percent were required to design sidewalks more than 1.220 m (48 in) wide (NAHB, 1995).

### 4.4.14 Maintenance

Sidewalks are prone to damage caused by environmental conditions. Maintaining sidewalk elements in good condition is an essential part of providing access to public rights-of-way. Sidewalks in poor repair can limit access and threaten the health and safety of pedestrians. If sidewalks are in poor condition or nonexistent, pedestrians are forced to travel in the street.

A public information program by the Campaign to Make America Walkable indicated that 3 of the top 10 most frequently cited roadway safety and sidewalk design problems were the following maintenance issues (The Campaign to Make America Walkable, 1997):

1. Missing sections of sidewalk, especially on key walking routes
2. Bad sidewalk surfaces, i.e., uneven or broken concrete or uplifted slabs over tree roots
3. Bad sidewalk maintenance, i.e., overhanging bushes or trees or unshoveled snow on sidewalks

Maintenance problems are usually identified by pedestrians who report the location to the municipal authorities. Identification of locations requiring maintenance may be done in conjunction with a city's accessibility improvement program. Effective maintenance programs are quick to identify conditions that can impede access and respond with repairs. Some cities survey and repair all sidewalks in regular cycles. Other cities make or enforce repairs only if a complaint is filed. Cities also might have pavement management programs and personnel devoted entirely to inspecting and repairing damaged access routes. Assessing sidewalks for accessibility should be an integral part of maintenance survey programs.

Sidewalk inspectors typically look for conditions that are likely to inhibit access or cause pedestrians to injure themselves. The following list of common sidewalk maintenance problems was generated from promotional material created for home owners by the Bureau of Maintenance in the City of Portland, Oregon (1996) and the Division of Engineering for the Lexington–Fayette County Urban Government (1993):

- *Step separation* — a vertical displacement of 13 mm (0.5 in) or greater at any point on the walkway that could cause pedestrians to trip, lock up the wheels of a wheelchair, or prevent the wheels of a wheelchair from rolling smoothly
- *Badly cracked concrete* — holes and rough spots ranging from hairline cracks to indentations wider than 25 mm (1 in)
- *Spalled areas* — fragments of concrete or other building material detached from larger structures; also losses of aggregate and cement leaving holes or depressions greater than 50 mm x 50 mm (2 in x 2 in) in the sidewalk
- *Settled areas that trap water* — sidewalk panels with depressions, reverse cross-slopes, or other indentations that cause the sidewalk path to be lower than the curb; these depressions cause silt and water to settle on the walkway path and might require replacement.
- *Tree root damage* — roots from trees growing in adjacent landscaping that cause the walkway surface to buckle and crack, impeding access
- *Vegetation overgrowth* — ground cover, trees, or shrubs on properties or setbacks adjacent to the sidewalk that have not been pruned. Overgrown vegetation can encroach onto the walkway and pose obstacles, inhibiting pedestrian access.
- *Obstacles* — objects located on the sidewalk, in setbacks, or on properties adjacent to the sidewalk that obstruct passage space. Obstacles commonly include trash receptacles, parked cars, and private mailboxes.
- *Sidewalks of materials other than specified by the municipality* — the use of materials other than those specified by the municipality in the construction of sidewalks and driveway aprons. Materials not approved for sidewalk construction can erode quickly, cause excessive slippage, or be inappropriate to the atmosphere of a particular area.
- *Driveway flares* — that do not comply with standard criteria set by the municipality
- *Any safety issue* — that a pedestrian or sidewalk inspector believes merits attention

Although sidewalks are elements of the public right-of-way, many city charters assign the owner of the adjacent property with responsibility for sidewalk upkeep. It is common for city charters to specify that the city cannot be held liable for any accident or injury due to sidewalk conditions.

Home owners are commonly allowed to decide whether to hire a contractor, perform repairs on their own, or have the city do the repair. The home owners' association in some neighborhoods address right-of-way maintenance to minimize the cost to individual members. Some cities subsidize property owners for repairing sidewalks. Local laws also might dictate whether a home owner must engage a professional contractor to undertake sidewalk repair. If municipal inspectors review and approve sidewalk repairs, the finished sidewalks are more likely to meet pedestrian access needs.

***Figure 4-56:***

***Traffic sign indicating upcoming steep grade (US DOT, 1988).***

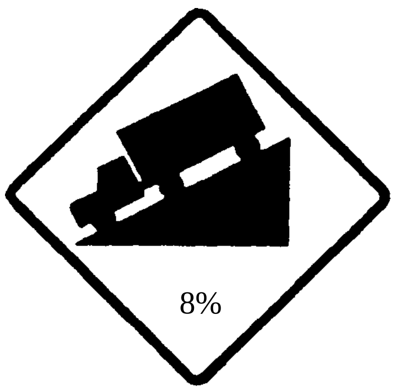



***Figure 4-57:***

***Pedestrian sign indicating upcoming steep grade.[1]***


[1] This sign is not currently included in the *Manual on Uniform Traffic Control Devices* (MUTCD). Before using any traffic control device that is not included in the MUTCD, the interested State or locality should submit a request for permission to experiment to FHWA's Office of Highway Safety (HHS-10), 400 Seventh Street, SW, Washington, DC 20590. Guidelines for conducting an experiment can be found in Part 1A-6 of the MUTCD.

### 4.4.15 Signs

Most agencies rely on the MUTCD for sign guidelines. For font recommendations, the MUTCD references the *Standard Alphabets for Highway Signs and Pavement Markings,* which permits a series of six letter types on signs. Each letter type features a different stroke width-to-height ratio (Office of Traffic Operations, FHWA, 1982). Various sign shapes, colors, and lettering are used for each type of sign (warning, street, regulatory, etc.) (US DOT, 1988). Braille and raised lettering are not addressed in the MUTCD.

ADAAG Section 4.30 also provides guidelines for signage. ADAAG specifications are targeted at indoor facilities and might not be applicable to all outdoor spaces. According to ADAAG, "letters and numbers on signs shall have a width-to-height ratio between 3:5 and 1:1 and a stroke width-to-height ratio between 1:5 and 1:10" (ADAAG, U.S. Access Board, 1991). MUTCD requirements for size and stroke meet and might even exceed ADAAG specifications. ADAAG Section 4.30 also provides guidelines for character height, raised and brailled characters and pictorial symbol signs, finish and contrast, mounting location and height, and symbols of accessibility.

Pedestrian signs should not be placed in locations where they obstruct the minimum clearance width or protrude into the pathway.

The majority of signs in the public right-of-way are directed at the motorist. Although these signs often affect pedestrians, they are usually not intended for or positioned to be seen by sidewalk users. For example, the street name signs on many large arterials are hung in the center of the intersection. This location is essentially invisible to pedestrians traveling along the sidewalk. Pedestrians might even be put in danger because important safety information, such as yield signage, is not easily visible.

Targeting more signs toward pedestrians would improve safety and permit them to identify routes requiring the least effort for travel. Warning signs similar to standard traffic warning signs (Figure 4-56) would provide information on sidewalk characteristics such as steep grades (Figure 4–57). To date, these types of signs have not been introduced into the MUTCD. Inclusion in this report does not constitute FHWA endorsement. Pedestrian-oriented signage containing access information for trails has been developed as part of the Universal Trail Assessment Process (UTAP) (see Sections 5.1 and 5.4.9). Objective signage provides users with reliable information they can use to make informed choices about their travel routes. In the sidewalk environment, signage should be supplemented with audible or tactile information to be accessible to people with visual impairments.

## 4.5 Conclusion

Many factors work in concert to make sidewalks and sidewalk elements accessible. Although it is important to make individual features accessible, such improvements will not be useful unless the conditions of the sidewalk as a whole can be negotiated. Accessible sidewalks must be included as part of all new construction and alterations. In addition, regular maintenance programs should be implemented to keep existing routes safe and usable.

***Table 4-2.1:***
***Federal Accessibility Guidelines for Accessible Routes***

| | Maximum Allowable Running Grade without Handrails | Maximum Grade with Handrails and Level Landings | | Maximum Allowable Running Cross-Slope | Minimum Clearance Width | Maximum Allowable Vertical Change in Level | Minimum Allowable Vertical Clearance (Overhead) |
|---|---|---|---|---|---|---|---|
| Source | % | % | m | % | m | mm | m |
| ADA Standards for Accessible Design[1] (US DOJ, 1991) | 5.0[2] | 8.33[2] | 9.1 | 2.0 | 0.915[3] | 6[4] | 2.030 |
| UFAS (US DoD, et al., 1984) | 5.0[2] | 8.33[2] | 9.1 | 2.0 | 0.915[3] | 6[4] | 2.030 |

[1] The ADA Standards for Accessible Design are identical in content to ADAAG Sections 1–10. However, the Design Standards are enforceable by the U.S. Department of Justice.

[2] The ADA Standards for Accessible Design require people to use the least slope possible on accessible routes.

[3] Minimum clearance width may be reduced to 0.815 m (32 in) at an obstruction for a maximum length of 0.610 m (24 in).

[4] Changes in level between 6 mm (.25 in) and 13 mm (.5 in) are permitted if beveled with a maximum slope of 50 percent.

***Table 4-2.2:***
***ADAAG-Proposed Section 14 (1994) Accessibility Guidelines for Public Rights-of-Way***

| | Maximum Allowable Running Grade | Maximum Grade for a Specified Distance (Run) | | Maximum Allowable Running Cross-Slope | Minimum Clearance Width | Maximum Allowable Vertical Change in Level | Minimum Allowable Vertical Clearance (Overhead) |
|---|---|---|---|---|---|---|---|
| Source | % | % | m | % | m | mm | m |
| ADAAG-proposed Section 14 (1994) (U.S. Access Board, 1994b) | n/a[1] | n/a | n/a | 2.0 | 0.915 | 6[2] | 2.030 |

[1] Sidewalk slopes may be consistent with the slope of the adjacent roadway.

[2] Changes in level between 6 mm (.25 in) and 13 mm (.5 in) are permitted if beveled with a maximum slope of 50 percent.

***Table 4-2.3:***

***State Guidelines for Sidewalks***

| Source | Maximum Allowable Running Grade (%) | Maximum Grade for a Specified Distance (Run) (%) | Maximum Grade for a Specified Distance (Run) (m) | Maximum Allowable Running Cross-Slope (%) | Minimum Clearance Width (m) | Maximum Allowable Vertical Change in Level (mm) | Minimum Allowable Vertical Clearance (Overhead) (m) |
|---|---|---|---|---|---|---|---|
| FL Ped. Planning and Dgn. Guidelines (University of NC Hwy. Safety Research Ctr., 1996) | 5.0 | n/a[1] | n/a[1] | 2.0 | 1.220 | n/a | n/a |
| Oregon Pedestrian Design Guidelines | 5.0 | 8.33 | 9.1 | 2.0 | 1.0 | n/a | 2.1 |
| Architectural Barriers Act (Texas Department of Licensing and Regulation, 1997) | 5.0 | 8.33 | 9.1 | 2.0 | 0.915 | 6[2] | 2.030 |

[1] Florida directs people to the ADA for maximum grade requirements.

[2] Changes in level between 6 mm (.25 in) and 13 mm (.5 in) are permitted if beveled with a maximum slope of 50 percent.

***Table 4-2.4:***

***Additional Recommendations for Sidewalks***

| Source | Maximum Allowable Running Grade without Handrails (%) | Maximum Grade with Handrails and Level Landings (%) | Maximum Grade with Handrails and Level Landings (m) | Maximum Allowable Running Cross-Slope (%) | Minimum Clearance Width (m) | Maximum Allowable Vertical Change in Level (mm) | Minimum Allowable Vertical Clearance (Overhead) (m) |
|---|---|---|---|---|---|---|---|
| Accessibility for Elderly and Handicapped Peds. (Earnhart and Simon, 1987) | 5.0 | 8.33 | 9.1 | 2.0 | 0.915 | 6[1] | 2.030 |
| ANSI A117.1-1980 (ANSI, 1980) | 5.0 | 8.33 | 9.1 | 2.0 | 0.915 | 6[1] | 2.030 |
| ANSI A117.1-1992 (Council of American Building Officials, 1992) | 5.0 | 8.33 | 9.1 | 2.1 | 0.915 | 6[1] | 2.030 |
| Dgn. and Safety of Ped. Facilities (ITE Tech. Council Comm. SA-5, 1998) | 8.0 | 8.0 | 9.1 | 2.1 | 0.915 | n/a | n/a |

[1] Changes in level between 6 mm (.25 in) and 13 mm (.5 in) are permitted if beveled with a maximum slope of 50 percent.

***Table 4-3.1:***
***Federal Accessibility Guidelines for Curb Ramps (CR)***

| Source | Maximum Slope of Curb Ramps % | Maximum Cross-Slope of Curb Ramps % | Maximum Slope of Flared Sides % | Minimum Ramp Width m | Minimum Landing Length m |
|---|---|---|---|---|---|
| ADA Standards for Accessible Design[1] (US DOJ, 1991) | 8.33[2, 3] | 2.0 | 10.0[4, 5] | 0.915[6] | 0.915 |
| UFAS (US DoD, et al., 1984) | 8.33[2, 3] | 2.0 | 10.0[4, 5] | 0.915[6] | 0.915 |

[1] The ADA Standards for Accessible Design are identical in content to ADAAG Sections 1–10. However, the Design Standards are enforceable by the U.S. Department of Justice.

[2] The ADA Standards for Accessible Design require people to use the least slope possible on curb ramps that are part of accessible routes.

[3] If space prohibits a slope less than 8.33%, curb ramps to be constructed on existing sites may have a slope of 8.33% to 10% with a maximum rise of 150 mm (6 in) or a slope of 10% to 12.5% with a maximum rise of 75 mm (3 in).

[4] The flare guidelines do not apply if the curb ramp is located where a pedestrian does not have to walk across the ramp or if the flared sides are protected by handrails or guardrails.

[5] If the landing is less than 1.220 m long, the slope of the flared sides must not exceed 8.33%.

[6] Exclusive of flared sides.

***Table 4-3.2:***
***ADAAG-Proposed Section 14 (1994) Accessibility Guidelines for Curb Ramps (CR)***

| Source | Maximum Slope of Curb Ramps % | Maximum Cross-Slope of Curb Ramps % | Maximum Slope of Flared Sides % | Minimum Ramp Width m | Minimum Landing Length m |
|---|---|---|---|---|---|
| ADAAG-Proposed Section 14 (1994) (U.S. Access Board, 1994b) | 8.33[1, 2] | 2.0 | 10.0[3] | 0.915[4] | 0.915[5] |

[1] The U.S. Access Board recommends using the least slope possible.

[2] The slope of a parallel curb ramp should not exceed 8.33%, but is not expected to exceed 2.440 m in length.

[3] The flare guidelines do not apply if the curb ramp is located where a pedestrian does not have to walk across the ramp or if the flared sides are protected by handrails or guardrails.

[4] Exclusive of flared sides.

[5] The minimum allowable landing length is 0.915 m for parallel curb ramps and 1.220 m for perpendicular curb ramps.

***Table 4-3.3:***

***State and City Guidelines for Curb Ramps (CR)***

| Source | Maximum Slope of Curb Ramps % | Maximum Cross-Slope of Curb Ramps % | Maximum Slope of Flared Sides % | Minimum Ramp Width m | Minimum Landing Length m |
|---|---|---|---|---|---|
| FL Ped. Planning and Dgn. Guidelines (University of NC Hwy. Safety Research Ctr., 1996) | 8.33 | n/a | 8.33[1] | 1.0 | 1.220 |
| Ped. Compatibility Planning and Dgn. Guidelines (NJ DOT, 1996) | 8.33[2] | 2.0[2] | 10.0[1] | 1.220 | 1.220 |
| Ped. Dgn. Guide (City of Portland, 1997) | 8.33 | 2.0 | n/a | 0.915 | 1.220 |
| Architectural Barriers Act (Texas Department of Licensing and Regulation, 1997) | 8.33[2, 3] | 2.0 | 10.0[1, 4] | 0.915[5] | 0.915 |

[1] The flare guidelines do not apply if the curb ramp is located where a pedestrian does not have to walk across the ramp or if the flared sides are protected by handrails or guardrails.
[2] The least possible slope should be used.
[3] If space prohibits a slope less than 8.33%, curb ramps to be constructed on existing sites may have a slope of 8.33 to 10% with a maximum rise of 150 mm (6 in) or a slope of 10 to 12.5% with a maximum rise of 75 mm (3 in).
[4] If the landing is less than 1.220 m long, the slope of the flared sides must not exceed 8.33%.
[5] Exclusive of flared sides.

***Table 4-3.4:***

***Additional Recommendations for Curb Ramps (CR)***

| Source | Maximum Slope of Curb Ramps % | Maximum Cross-Slope of Curb Ramps % | Maximum Slope of Flared Sides % | Minimum Ramp Width m | Minimum Landing Length m |
|---|---|---|---|---|---|
| Accessibility for Elderly and Handicapped Peds. (Earnhart and Simon, 1987) | 8.33[1] | n/a | 10.0[2, 3] | 0.915 | n/a |
| ANSI A117.1-1980 (ANSI, 1980) | 8.33[1, 4] | 2.0 | 10.0[2] | 0.915[5] | 0.915 |
| ANSI A117.1-1992 (Council of American Building Officials, 1992) | 8.33[1, 4] | 2.1 | 10.0[2] | 0.915[5] | 0.915 |
| Dgn. and Safety of Ped. Fac. (ITE Tech Council Comm SA-5, 1998) | 8.33 | n/a | 10.0 | 0.915 | n/a |
| Planning Dgn. and Maintenance of Ped. Facilities (Bowman, Fruin, and Zegeer, 1989) | 8.33[1] | n/a | 10.0[2, 3] | 0.915[6] | n/a |

[1] If space prohibits a slope less than 8.33%, curb ramps to be constructed on existing sites may have a slope of 8.33 to 10% with a maximum rise of 150 mm (6 in) or a slope of 10% to 12.5% with a maximum rise of 75 mm (3 in).
[2] The flare guidelines to not apply if the curb ramp is located where a pedestrian does not have to walk across the ramp or if the flared sides are protected by handrails or guardrails.
[3] If the landing is less than 1.220 m long, the slope of the flared sides must not exceed 8.33%.
[4] The least possible slope should be used.
[5] Exclusive of flared sides.
[6] In areas with snow removal, 1.220 m is the minimum recommended ramp width.